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digit FastTrack

YOUR HANDY GUIDE TO EVERYDAY TECHNOLOGY

to Space Exploration

Taking off | The space race | Man on the moon
The end of the space race | Space stations
Other countries & private programmes
Living in space | Future of manned missions

A 9.9 Media Publication

FAST TRACK *to*

SPACE EXPLORATION

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CHAPTERS

SPACE EXPLORATION
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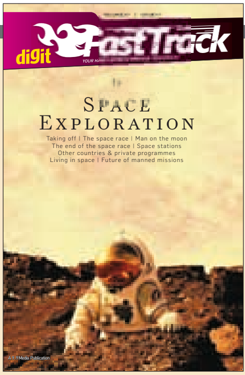

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The need to explore space

It is a question born out of common sense as much as anything else: "Why should we spend billions of dollars, enormous human energy and the efforts of some of mankind's leading minds on something like exploring space when there are already so many problems here on Earth?"

There are several answers offered by some of the world's greatest thinkers, but more often than not, it all boils down to one thing: discovery. The exploration of the unknown – be it scientific or in terms of travel – is not just about quenching our innate curiosity, it's the only way we can come across new things. And something truly new, more often than not, leads to great and positive changes.

Imagine a world where Christopher Columbus was denied the opportunity to sail westwards on his notion that Earth is round and eventually land in India. He would never have discovered the Americas and who knows how the world would look today.

Discovery has no practical purpose – those are by-products of it. There are already enough examples of space technology being adapted to solve problems on Earth, from shock-absorbing helmets to space shuttle fuel pump technology that's being adapted into a device that helps heal a child's heart.

Of course, this isn't a good enough explanation for many and while we wouldn't claim to be able to convince you, it would be worthwhile to spend some time thinking about these famous quotes from some of the visionaries and thinkers of our time, helpfully compiled in a longer list at *www.spacequotes.com.*

"I don't think the human race will survive the next thousand years, unless we spread into space. There are too many accidents that can befall life on a single planet. But I'm an optimist. We will reach out to the stars."

— Stephen Hawking, theoretical physicist and cosmologist

"The urge to explore has propelled evolution since the first water creatures reconnoitred the land. Like all living systems, cultures cannot remain static; they evolve or decline. They explore or expire... Beyond all rationales, space flight is a spiritual quest in the broadest sense, one promising a revitalisation of humanity and a rebirth of hope no less profound than the great opening out of mind and spirit at the dawn of our modern age."

— Buzz Aldrin, the second man to walk on the moon

"The crossing of space ... may do much to turn men's minds outwards and away from their present tribal squabbles. In this sense, the rocket, far from being one of the destroyers of civilisation, may provide the safety-value that is needed to preserve it."

— Arthur C. Clarke, science fiction author

And of course, no speech summed up the need for exploration better than US President John F. Kennedy's announcement of going to the moon at Rice University in 1962, an excerpt of which is presented here:

"We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win.

Many years ago the great British explorer George Mallory, who was to die on Mount Everest, was asked why did he want to climb it. He said, "Because it is there."

Well, space is there, and we're going to climb it, and the moon and the planets are there, and new hopes for knowledge and peace are there. And, therefore, as we set sail we ask God's blessing on the most hazardous and dangerous and greatest adventure on which man has ever embarked."

TAKING OFF

There were a few technologies that needed to be mastered before man himself could go to space. And yes, monkeys and dogs have been there first!

Before sending man into space, there was the obvious problem of building a machine that managed to break out of the Earth's cocoon of spheres and go beyond. While the first human space-flight wouldn't happen until 1961, the stepping stones were laid down from as early as 50 years before that.

Much like any great scientific achievement, the inspiration for it drew from fiction. In 1898, H. G. Wells published the much-acclaimed sci-fi novel *The War Of The Worlds.* Among its many fans was a young American physics student, Robert Goddard. Goddard went on to study the mechanics of rockets and was the first to suggest the idea of a liquid-fuelled rocket in

his famous 1919 paper '*A Method of Reaching Extreme Altitudes*'. Much of the basis for modern space technology still comes from this paper.

Meanwhile, German physicist Hermann Oberth was also studying how to send rockets into space and for his doctoral thesis, wrote Die Rakete zu den Planetenräumen (*By Rocket into Planetary Space*). The thesis was rejected, but Oberth self-published it as a book that found great admiration and following throughout Germany as well as Russia.

For the next 20 years, scientists from the US, Germany and Russia were at the forefront of research on rockets and space travel – a competition that was only enhanced once World War II started.

The V-2 rocket

One would think that with all the attention that the Space Race received during the Cold War, either the US or Russia would have been the pioneer of space exploration. But surprisingly, the Germans were at the forefront.

In the 1930s and the 1940s, one name became synonymous with space research across the world: Werner Von Braun. Von Braun was greatly influenced by the works of both, Goddard and Oberth, and started to work on liquid-fuelled rockets from an early age. In the 1930s, when the Nazi party came into power, Von Braun was enlisted by the army and by 1934, he had successfully launched two liquid-fuelled rockets, although neither of them reached space. This series of rockets would be known as the Aggregat series, and titled A-1, A-2 and so on.

Of course, Hitler's interest in the rockets was to use them as long-range ballistic missiles that would have a reach unparalleled by any other artillery on the planet. He personally met with Von Braun a few times and finally gave the go-ahead for A-4.

It was this fourth Aggregat rocket that would turn out to be the most significant in mankind's history. More famously known as the V-2 rocket, this would be the first man-made machine to reach 100 kilometres from the surface of the earth – the demarcating line between Earth's atmosphere and outer space.

There were some key elements and advancements in the V-2 rocket which no American or Russian scientists had managed at the time. The liquid-fuel, of course, was the most important part. The rocket used an ethanol-water mixture as fuel and liquid oxygen as the oxidizer, a combination of which allowed it to reach heights of 80 kilometres – high enough to be able to attack London.

More importantly, being a combat ballistic missile, the rocket needed


Werner Von Braun holding a model of the V-2 rocket

to have some sort of guidance system. Von Braun's team used an ingenious combination of gyroscope sensors and rudders to achieve this.

But like with so many artefacts of war, the V-2 rocket was rushed out of production as a morale-boosting weapon for the Nazi army, which was getting hammered by the Allied Forces. So while it managed to do what it was asked, it didn't fulfil the lofty ambitions of Von Braun. Germany eventually lost the war and American and Russian forces managed to capture the plans and even some of the scientists – including Von Brain – responsible for developing the rocket. This knowledge, combined with their pre-existing space programmes, led to both the US and the Russians kicking off the Space Race.

The first photo from space

When the Second World War ended, the US and Russia both stepped up their space programmes with the help of their newfound information from Germany. Once again, it was all about building a missile that was capable of long ranges – the world's first ICBM (Intercontinental Ballistic Missile).

Both sides were using the V-2 rocket as the basis of building their missiles, with the Americans having an obvious advantage since they had captured Von Braun and got him to work on their space programme. The Russians also had a few German scientists and most of Von Braun's plans to aid them in their research.

In early tests, the Americans used the V-2 rocket itself to develop their

missile. But while the Russian space programme was centralised and unified, the American one was fragmented, with several groups competing amongst themselves to achieve significant advances. Of course, this also meant that scientists got ample room to play around with the gadgetry. For example, while the V-2 rocket was already able to reach space, the Douglas Aircraft Company and the Guggenheim Aeronautical Laboratory got together to build and send the WAC Corporal into space – the first American rocket meant for scientific purpose. It also used a different mixture of liquid elements as its fuel (aniline and furfuryl alcohol) and nitric acid as the oxidizer. While successful, the WAC Corporal was nothing more than an experiment.

The most significant non-military achievement of this era, though, was in 1946 when a team of researchers strapped a camera onto a V-2 rocket and managed to take the first photo of Earth from Space.

Launched from the White Sands Missile Range in New Mexico, the V-2 rocket was equipped with a standard 35-millimetre video camera that would snap a picture at an interval of 1.5 seconds. Since the rocket would come back down and crash, the film of the camera was encased in a protective reinforced steel box. The rocket climbed above the 100-kilometre line and fell back down as expected. The film was intact and provided the first view of the Earth from space.

The First Living Organism In Space

With the focus of the space programmes slowly turning to the ability to send humans into space and find out more about 'the great beyond', it became extremely important to find out the effect that radiation and spaceflight would have on living organisms.

In 1947, the Americans sent the first living organisms into space aboard a V-2 rocket. A few fruit flies were packed into a container with cotton and rye seeds, and were successfully recovered alive after the rocket reached space and returned.

With monkeys being the closest relatives of humans in the animal world, it was only a matter of time before scientists began experimenting with sending them into space. Albert I was the first monkey sent aboard a V2 rocket in 1948, but he suffocated and died during the flight – and the rocket never reached space either.

Albert II became the first monkey to reach space aboard a V-2 rocket in 1949, and he did not suffocate either. But due to a parachute failure, Albert II died on impact. Albert III and IV followed – with both not surviving

the flight – before the Americans stopped experimenting with monkeys.

The failure of the rocket's parachute system also caused some other fatalities, including the first mouse in space in 1950.

Meanwhile, the Russians had successfully emulated the V-2 into a new Russian-made rocket called the R1. In 1951, the Soviet Union was the first to send dogs into space. Tsygan and Dezik were launched aboard the R-1 IIIA-1 which not only crossed the 100-km barrier, but also came back without any incident, with both the dogs successfully surviving the spaceflight.

Sputnik

Over the next few years, the Cold War grew more tense and fierce. The space programmes of both, Russia and USA picked up pace and started capturing the world's imagination. It was partly also out of the number of fiction pieces surrounding the subject that aroused people's curiosity.

While each had its own share of great achievements, the Soviet Union was the first to accomplish what both space programmes were created for – the ICBM. In August of 1957, the R-7 Semyorka became the first successful intercontinental ballistic missile and laid the foundation for an even greater accomplishment – the first artificial satellite to orbit the earth.

The story of the artificial satellite actually begins in 1952, when the International Council of Scientific Unions decided to establish July 1, 1957 to December 31, 1958 as the International Geophysical Year (IGY) because the scientists knew that the cycles of solar activity would be at a high point then. In October 1954, the council adopted a resolution calling for artificial satellites to be launched during the IGY to map the Earth's surface.

In July 1955, America announced plans to launch an Earth-orbiting satellite for the IGY and solicited proposals from various Government research agencies to undertake development. In September, it chose and started a project called Vanguard.

But unbeknownst to the US, the Soviets had already started their own plans for the same through a project headed by Sergey Korolev. The Politburo soon announced their own plans to launch an artificial satellite and this formally kicked off the Space Race.

While many expected the Americans to manage to successfully put their own satellite in orbit first, the Russians pipped them to the post.

In 1957, on October 4 at 10:28 p.m. Moscow time, a brilliant and deafening detonation of smoke and flame illuminated the Soviet Union's rocket test site near Tyuratam, Kazkhistan, as the 32 nozzles announced the rise

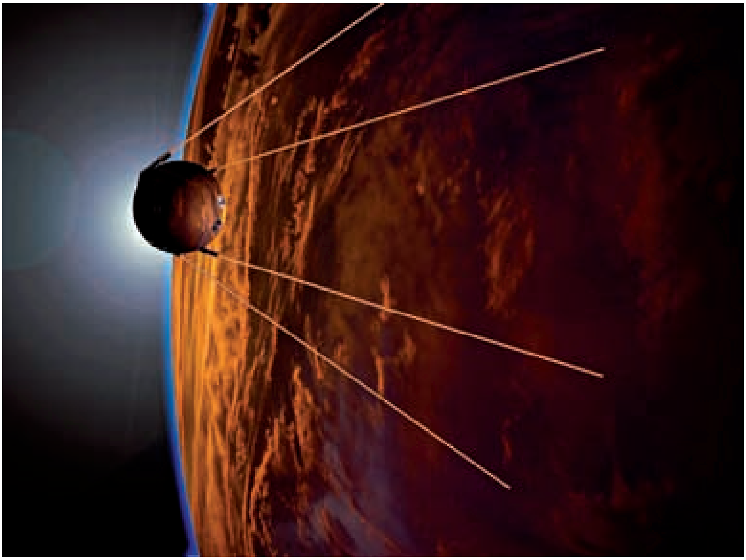


Image Credit: Gregory R Todd

An artist's impression of Sputnik-I in orbit

of the Russian R-7 intercontinental ballistic missile. After five minutes and 230 kilometres, the last of the R-7's engines shut down for good. Soon after, pneumatic locks were activated, a nosecone fairing separated, and an antenna spike was released. Then, in one final act that signalled the dawn of the space age, a pushrod connected to a bulkhead of the R-7 was activated, shoving a beach ball-sized sphere into the cold, harsh blackness of space. Sputnik had arrived.

Sputnik 1 became the first artificial satellite to be put into the Earth's orbit. A 22-inch aluminium sphere with four spring-loaded whip antennae trailing, it weighed only 83 kgs, measured a little less than two feet in diameter, and travelled an elliptical orbit that took it around the Earth every 96 minutes. It carried a small radio beacon that beeped at regular intervals and could, by means of telemetry, verify exact locations on the earth's surface. Some US cold warriors suggested that this was a way for the Soviets to obtain targeting information for their ballistic missiles, but that doesn't seem to have actually been the case. The satellite itself fell from orbit three months after launch on January 4, 1958.

It wouldn't be until two months after Sputnik 1 crashed back on earth that the US would be able to launch its own Explorer 1 satellite into space on March 17, 1958.

Over the next couple of years, the Space Race would heat up and the Soviet Space Programme emerged as the leader. The Luna programme was launched to develop the first lunar probe. Although the Luna 1 was unsuccessful in doing so, it did become the first man-made object to reach Earth's escape velocity. The objective of the programme was successfully achieved when the Luna 2 became the first man-made object to reach the moon in 1959. Luna 3 rounded the Moon later that year, and returned the first photographs of its far side, which can never be seen from Earth.

Meanwhile, the US space programme also achieved some success through missions like the Explorer 6, which was the first artificial satellite to click photographs of the Earth from its own orbit.

Laika and Sputnik 5

As it became clear that the technology now existed to send man into orbit, the question was whether a living organism would be able to survive the launch and endure weightlessness. Like before, the Soviets turned to dogs to test this.

Laika, a stray dog, was chosen to be put aboard the Sputnik 2, which was launched mere months after the path-defining Sputnik 1 on November 3, 1957. Laika survived the launch and weightlessness, but died of heat inside the satellite.

At the time, the question to send the dog on the ill-fated mission wasn't questioned, but scientists involved in the programme have later expressed their regrets. One of them, Oleg Gazenko, later said, "Work with animals is a source of suffering to all of us. We treat them like babies who cannot speak. The more time passes, the more I'm sorry about it. We shouldn't have done it... We did not learn enough from this mission to justify the death of the dog."

Meanwhile, a separate spacecraft called the Vostok was built by the Soviet Union to make it easier and safer to go into space. In its third test flight in 1960, the Vostok carried the Sputnik 5 satellite with its crew of two dogs – Belka and Strelka – as well as two rats, 40 mice and a variety of plants. The spacecraft was able to successfully go into orbit and return thereafter with all its occupants alive, making it the first time living organisms had been in Earth's orbit and returned to the planet safely.

With the proof of model established, it was finally decided that the Russians would be sending a man into space soon...

THE SPACE RACE

The increasing competition between the US and the USSR led to many rapid advancements, including the first man to orbit Earth

While the Soviets sought to unify all of their efforts into a centralised system, the Americans preferred having several different arms – the army, navy, private agencies, etc – trying their own experiments with a very light central cohesion. The result, naturally, was that the Soviets took a huge lead and managed to beat the Americans in launching the first artificial satellite, Sputnik, in 1957.

The effect of Sputnik's launch on the American public's minds was that of alarm and panic. Suddenly, it felt like they were behind the Soviets and the communist ideology was winning. The need for a centralised agency to take charge of the country's space efforts.

A turning point came in 1958 when US President Eisenhower asked his

science advisor, James R. Killian, to convene the President's Science Advisory Committee (PSAC) to come up with a plan for a new space flight organization. Quietly considering the creation of a new civil space agency for several months, PSAC worked with staff members from Congress and quickly came forward with a proposal that placed all non-military efforts relative to space exploration under a strengthened and renamed National Advisory Committee for Aeronautics (NACA), which had been around since 1915.

Eisenhower accepted the PSAC's recommendations and sponsored legislation to expand the NACA into an agency charged with the broad mission to "plan, direct, and conduct aeronautical and space activities"; to involve the nation's scientific community in these activities; and to widely disseminate information about these activities. An administrator appointed by the president was to head the National Aeronautics and Space Administration (NASA). During the summer of 1958 Congress passed the National Aeronautics and Space Act and the president signed it into law on 29 July 1958.

The new organisation, NASA, started functioning on October 1, 1958, less than a year after the launch of Sputnik 1. Headed by Dr. T. Keith Glennan, its first task was the development of a human space exploration program.

Yuri Gagarin, the first man in space

Both the newly-formed NASA and the Soviets had announced their intension of putting a man into space. And with the Soviets having already won the race to send the first artificial satellite into space, they weren't about to give up their lead.

The push on the Vostok programme resulted in the successful mission of sending dogs, rats and mice aboard the Sputnik 5 into Earth's orbit and bring them back to earth safely. The green signal was given shortly after that to send a man into space.

The Russians had already started preparing candidates for the first flight. To define this new breed of pilots, they came up with the term 'cosmonauts' – or sailors of the universe. Since the mission was a furthering of the abilities that would be needed of a trained pilot, the Soviets tapped their own Air Force for candidates. A severe test of sets brought the shortlist down to six: Yuri Gagarin, Anatoli Kartashov, Andrian Nikolayev, Pavel Popovich, Gherman Titov and Valentin Varlamov. They would come to be known as the Vanguard Six. This group went extensive training in a spacecraft simulator while Sergei Korolev – the lead rocket scientist in the Soviet programme – and his team worked on the Vostok rocket. They came

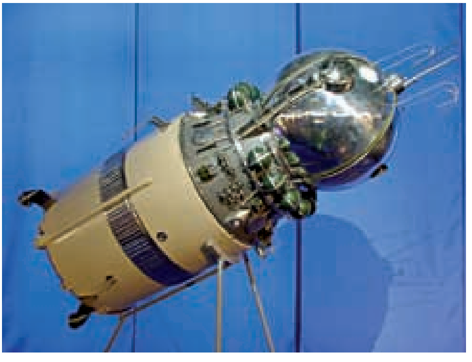
know of the news that NASA was getting ready for its first sub-orbital flight in 1961, so they decided to aim higher (literally) and be the first to send a man into Earth's orbit.

After the success of Sputnik 5, they conducted one last test of the Vostok 3KA rocket in which they sent a dummy, along with a dog, into orbit on an unmanned spacecraft that would be identical to the one they use for sending their first cosmonaut into space. Launched on March 9, 1961, the mission was a success as the rocket left the earth, entered orbit, and left that to re-enter Earth, following which the mannequin was safely ejected and the dog recovered in a detached descent module.

Finally, every go-ahead was given and the Soviets were ready to launch their first man into space. Colonel Yuri Gagarin was chosen for this prestigious mission – which, surprisingly, would also be his last space mission. On April 12, 1961, the era of human spaceflight began. The rocket lifted off – Gagarin yelling over the ride, "Let's ride!" – and the cosmonaut became the first human to orbit the Earth in his Vostok I spacecraft.

This was the first spacecraft to carry a human into space, occurring 25 days prior to the first US suborbital flight. Because of concerns of adverse reactions to due to experiencing weightlessness, the manual controls on the spacecraft were locked prior to launch and the entire flight was under the control of ground personnel. Gagarin, however, had the option of being able to manually control the flight if deemed absolutely necessary.

The spacecraft consisted of a nearly spherical cabin covered with ablative material. There were three small portholes and external radio antennas. Radios, a life support system, instrumentation, and an ejection seat were contained in the manned cabin. This cabin was attached to a service module that carried chemical batteries, orientation rockets, the main retro system, and added support equipment for the total system. This module was separated from the manned cabin on re-entry. After one orbit, the spacecraft



A model of the Vostok I spacecraft

re-entered the atmosphere and landed in Kazakhstan, about 1 hour and 48 minutes after launch.

The Vostok spacecraft was designed to eject the cosmonaut at approximately 7 km and allow him to return to earth by parachute. Although initial reports made it unclear whether Gargarin landed in this manner or returned in the spacecraft, subsequent reports confirmed that he did indeed eject from the capsule. Radio communications with earth were continuous during the flight, and television transmissions were also made from space.

Gagarin instantly became an international hero and is often referred to as the 'Columbus of the Cosmos'. For the next few years, he became the posterboy for Russia's seeming dominance over the US and he was paraded around the globe. When Gagarin finally returned to Russia and started training for a second mission, an air crash ended his life on March 27, 1968.

To commemorate the 50th anniversary of Gagarin's historic spaceflight, filmmaker Christopher Riley and the European Space Agency released a short film in 2011 titled First Orbit, which replicates what Gagarin must have seen in his first flight and complements it with archival audio footage. It can be seen online at *www.firstflight.org.*

Gagarin was soon followed into space by his colleague Gherman Titov, who went aboard the Vostok II on August 6, 1961, for the first full-day manned mission in space. Over the next few years, the Soviets would launch four more manned missions into space, including Valentina Tereshkova, who would become the first woman in space on June 19, 1963.

Cosmonaut Yuri Gagarin preparing to become the first man in space

Project Mercury

Let's rewind the clock a little. In 1958, two months after NASA was formed, its administrator Dr. T. Keith Glennan announced that the organisation would be looking to send a man into space as well. Obviously, the Soviets won this fight, but to understand the future missions NASA undertook, it's important to know about this programme, which would be called 'Project Mercury'.

Mercury had three main objectives: Place a manned spacecraft in orbital flight around the earth; Investigate man's performance capabilities and his ability to function in the environment of space; Recover the man and the spacecraft safely.

The first US spacecraft was a cone-shaped one-man capsule with a cylinder mounted on top. Two meters long, 1.9 meters in diameter, a 5.8 meter escape tower was fastened to the cylinder of the capsule. The blunt end was covered with an ablative heat shield to protect it against the 3000 degree heat of entry into the atmosphere. The capsule had very little room inside for the one person it held. In fact, the astronaut had to stay in his seat throughout the journey.

The Mercury program used two launch vehicles: A Redstone for the suborbital and an Atlas for the four orbital flights. Prior to the manned flights, unmanned tests of the booster and the capsule were made, carrying a chimpanzee.


Image Credit: Pyramid Design

A rendering of the Mercury spacecraft over the Sahara desert

The Mercury spacecraft was the first of its kind to have a failsafe mechanism to ensure that the pilot would not be harmed in case of a malfunction in the launch process. The Launch Escape System (LES) was a contraption of booster rockets attached to the spacecraft that would fire in case the launch rocket malfunctioned. The spacecraft would thus be boosted clear of the explosion and, after deploying a parachute, land safely.

Through a rigorous selection programme, the Mercury project narrowed down seven potential pilots from the US Air Force for the spacecraft. Known popularly as the Mercury 7, they were Scott Carpenter, Gordon Cooper, John Glenn, Gus Grissom, Wally Schirra, Alan Shepard and Deke Slayton.

While the Soviets preferred the term 'cosmonaut', they dubbed their men 'astronauts'. The term was a cross between 'aeronauts', as ballooning pioneers were called, and 'Argonauts', the legendary Greeks in search

of the Golden Fleece. These new explorers were being prepared to sail into the new, uncharted vastness of space.

Each astronaut named his capsule and Shepard included a 7 in the name because it was the seventh one made. The other astronauts, to show their support for each other, also added a 7 in their names.

Less than a month after Yuri Gagarin's historic spaceflight, on May 5, 1961, at 9:34 am, the Freedom 7 blasted off from Cape Canaveral in Florida to take Alan Shepard into Space – became the first American and the second person ever to do so. Unlike Gagarin, though, Shepard's spacecraft wasn't completely automatic. He would thus become the first person in history to pilot a spaceship and also the first to land back on Earth in it, since Gagarin had parachuted out of it. It should be noted, however, that while Gagarin managed to get to the Earth's orbit, Shepard's flight was only sub-orbital. Soon after this, Grissom also went on a sub-orbital flight aboard the Liberty Bell 7.

On February 20, 1962, an Atlas rocket successfully carried John Glenn and the hopes of an entire nation into orbit aboard Friendship 7, a flight that ushered in a new era of space travel for America. Glenn was soon followed into orbit by colleagues Carpenter, Schirra and Cooper.

Among the original Mercury 7 astronauts, only Deke Slayton didn't make a flight due to medical reasons, but he did go on to fly in Space as part of the Apollo-Soyuz Test Project crew.

These manned space flights were accomplished with complete pilot safety and without change to the basic Mercury concepts. It was shown that man can function ably as a pilot-engineer-experimenter without undesirable reactions or deteriorations of normal body functions for periods up to 34 hours of weightless flight. The Mercury experience also helped NASA develop techniques and philosophies to insure well-trained flight and ground crews and correctly prepared space vehicles.

Going to the moon

On paper, Project Mercury was a success in proving America's ability to safely take man into space and bring him back. It also ticked several other boxes in the technological spectrum. But politically and publicly, Mercury failed to make a dent.

The Soviets had won in every aspect of space missions by being first in making an ICBM, launching Sputnik into orbit and then sending Gagarin into the great beyond before the Americans could even send their astronaut

into sub-orbit. The year was 1961 and US President John F. Kennedy was faced with a dilemma.

He realised the importance of the Space Race given the Cold War they were engaged in, and the constant beating at the hands of the Soviets was leaving the American public disillusioned and alarmed. Kennedy needed a big win and so he called upon his Vice President, Lyndon Johnson, to sit down with the NASA officials and figure out a project which they could accomplish before the Soviet Union.

After several meetings, Johnson and NASA administrator James Webb noted that a mission to land a man on the moon was far enough into the future that they could achieve it first.

On May 25, 1961, just three short weeks after Alan Shepard's legendary flight, President Kennedy went to Congress for an address on "Urgent National Needs."

Kennedy told Congress and the nation that "space is open to us now", and said that space exploration may hold the key to our future here on Earth. Backing the pre-existing Apollo programme and making it into NASA's prime concern, he laid forth an audacious challenge:

"I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to Earth."

Project Gemini

While Apollo was going to be the project that finally took man to the moon, it was still a long way away from what NASA had achieved with Project Mercury at the time. There needed to be a bridge between Mercury and Apollo for the scientists to learn more about space travel, vehicular technology and its effects on astronauts. Out of this need, 'Project Gemini' was born on January 3, 1962.

The Gemini Programme had four objectives: 1) To subject astronauts to long duration flights – a requirement for projected later trips to the moon or deeper space; 2) to develop effective methods of rendezvous and docking with other orbiting vehicles, and to manoeuvre the docked vehicles in space; 3) to perfect methods of re-entry and landing the spacecraft at a pre-selected land-landing point; 4) to gain additional information concerning the effects of weightlessness on crew members and to record the physiological reactions of crew members during long duration flights.

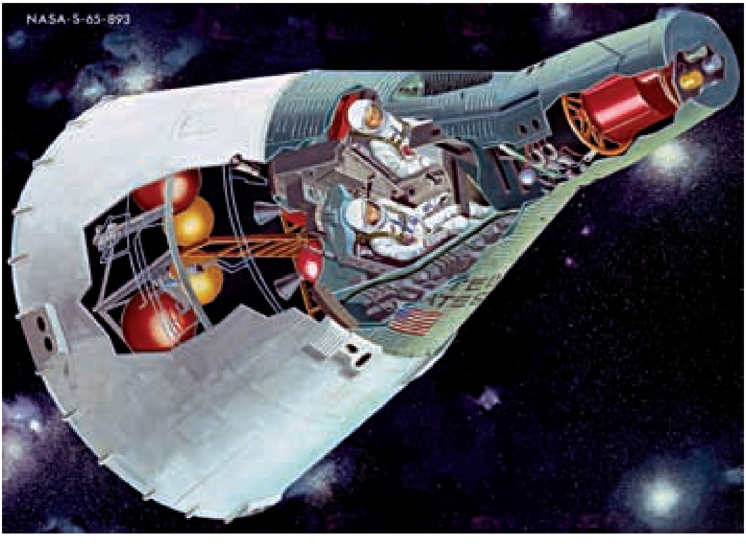
The name 'Gemini' was derived from the spacecraft's new requirement

of holding two astronauts, seated side-by-side. The word gemini is Latin for “twins”.

The Gemini spacecraft was an improvement on Mercury (it was originally called Mercury Mark II) in both, size and capability. Gemini weighed more than 3.5 tons – twice the weight of Mercury – but ironically seemed more cramped, having only 50 percent more cabin space for twice as many people. Ejection seats replaced Mercury’s escape rocket, and more storage space was added for the longer Gemini flights. The long duration missions also required fuel cells instead of batteries for generating electrical power.

Unlike Mercury, which had only been able to change its orientation in space, Gemini needed real manoeuvring capability to rendezvous with another spacecraft. Gemini would have to move forward, backward and sideways in its orbital path, even change orbits. The complexity of rendezvous demanded two people on board, and more piloting than had been possible with Mercury. It also required the first on-board computers to calculate complicated rendezvous manoeuvres.

Gemini rode into orbit on a Titan II launch vehicle. The target for rendezvous operations was an the Agena – an unmanned spacecraft controlled by NASA, launched ahead of the Gemini. After meeting up in orbit, the



A cutaway illustration of the Gemini spacecraft

nose of the Gemini capsule then fit into a docking collar on the Agena.

Ed White becomes the first American to go on a spacewalk

To avoid long delays between flights, Gemini spacecraft was made more serviceable, with subsystems that could be removed and replaced easily. An adapter module fitted to the rear of the capsule (and jettisoned before re-entry) carried on-board oxygen, fuel and other consumable supplies.

Gemini gave US astronauts their first real experience with living and working in space. They had to learn to sleep and keep house on long flights in crowded quarters, both of which were difficult. These astronauts also made the first forays outside their spacecraft, which required a new spacesuit design. Space walks, however, proved more difficult than expected.

The Gemini IV mission – the second manned flight in the programme – saw Ed White become the first American to perform extravehicular activity (EVA). On June 3, 1965, White stepped out of the spacecraft and used a zip-gun (which propels the astronaut using pressurised oxygen) to go out as far as 15 feet from the capsule. So enjoyable was the experience that White refused to come back in even when ordered by Command Pilot James McDivitt. White tried making up excuses of having to take photographs before finally succumbing to the orders. As he was re-entering the spacecraft, he sighed, “This is the saddest moment of my life.”

It was during the Gemini program that space flight became routine. Ten manned missions left the launch pads of Cape Canaveral in less than 20 months, and the Manned Spacecraft Centre outside Houston (later Johnson Space Centre) took over the role of Mission Control. Ground operations became smooth and efficient, due in part to fleetingly short launch windows – the Gemini XI “window” opened for only two seconds – dictated by the need to rendezvous with targets already in orbit. Meanwhile, sixteen new astronauts chalked up experience in space.

By Gemini’s end, an important new capability – orbital rendezvous and

docking – had become routine, and space doctors had gained confidence that humans could live, work and stay healthy in space for days or even weeks at a time. Gemini also completed a long list of on-board science experiments, including studies of the space environment and Earth photography. Above all, the program added nearly 1,000 hours of valuable space-flight experience in the years between Mercury and Apollo, which was nearing flight readiness by 1966, when the Gemini programme was wrapping up. Five days before the launch of the last Gemini, Lunar Orbiter 2 had been sent to the Moon, already scouting out Apollo landing sites.

Project Apollo

Project Apollo's goals went beyond landing Americans on the Moon and returning them safely to Earth. They included 1) establishing the technology to meet other national interests in space; 2) achieving pre-eminence in space for the United States; 3) carrying out a program of scientific exploration of the moon, 4) developing man's capability to work in the lunar environment.

The docking abilities of the Gemini programme were one of the most important parts of the puzzle in figuring out how to get man on the moon. NASA had considered various different ways to get the astronauts to Earth's natural satellite, including a direct flight to the moon in a single rocket as well as a Lunar Surface Rendezvous, where two spacecraft would be launched to the moon simultaneously – one manned and one unmanned, with the latter carrying material to make the return possible.

But after much deliberation, it was finally decided that NASA would use a Lunar Orbit Rendezvous model of mission, in which two docked spacecraft were launched from Earth. They would travel to the orbit of the moon, upon which one part of the spacecraft would remain in orbit while the astronauts use the other part to make their way to the moon. This idea made it easier for the spacecraft to launch again from the moon (since it would now be a smaller and lighter machine), and once it docked with the orbiting add-on, it would get the extra power needed to return home.

The flight mode, Lunar Orbit Rendezvous, was selected in 1962. The boosters for the program were the Saturn IB for Earth orbit flights and the Saturn V for lunar flights.

Apollo was a three-part spacecraft: the Command Module (CM), which housed the crew, spacecraft operations systems, and re-entry equipment; the Service Module (SM) which carried most of the consumables (oxygen, water, helium, fuel cells, and fuel) and the main propulsion system (when

together, the two modules are called CSM; and the lunar module (LM), to take two of the crew to the lunar surface, support them on the Moon, and return them to the CSM in lunar orbit.

When attached together, the total length of the Command and Service Module (CSM) was 11 metres with a maximum diameter of 3.9 metres. Including propellants and expendables, the launch mass was approximately 28,800 kg, of which the Command Module had a mass of over 5550 kg and the Service Module over 23,000 kg.

Telecommunications included voice, television, data, and tracking and ranging subsystems for communications between astronauts, CM, LM, and Earth. Voice contact was provided by an S-band uplink and downlink system. Tracking was done through a unified S-band transponder. A high gain steerable S-band antenna consisting of four 79-cm diameter parabolic dishes was mounted on a folding boom at the aft end of the SM. Two VHF scimitar antennas were also mounted on the SM. There was also a VHF recovery beacon mounted in the CM. The CSM environmental control system regulated cabin atmosphere, pressure, temperature, carbon dioxide, odours, particles, and ventilation and controlled the temperature range of the electronic equipment.

The Command Module was a conical pressure vessel with a maximum diameter of 3.9 m at its base and a height of 3.65 m. It was made of an aluminum honeycomb sandwich bonded between sheet aluminium alloy. The base of the CM consisted of a heat shield made of brazed stainless steel honeycomb filled with a phenol epoxy resin as an ablative material and varied in thickness from 1.8 to 6.9 cm. At the tip of the cone was a hatch and docking assembly designed to mate with the lunar module.

The Command Module was divided into three compartments. The forward compartment in the nose of the cone held the three 25.4-metre diameter main parachutes, two 5-metre drogue parachutes, and pilot mortar chutes for Earth landing. The aft compartment was situated around the base of the CM and contained propellant tanks, reaction control engines, wiring, and plumbing. The crew compartment comprised most of the volume of space. Three astronaut couches were lined up facing forward in the centre of the compartment. A large access hatch was situated above the centre couch. A short access tunnel led to the docking hatch in the nose. The crew compartment held the controls, displays, navigation equipment and other systems used by the astronauts. The CM had five windows: one in the access hatch, one next to each astronaut in the two outer seats, and two forward-


The Apollo 15 Command and Service Module as viewed from the Apollo Lunar Module

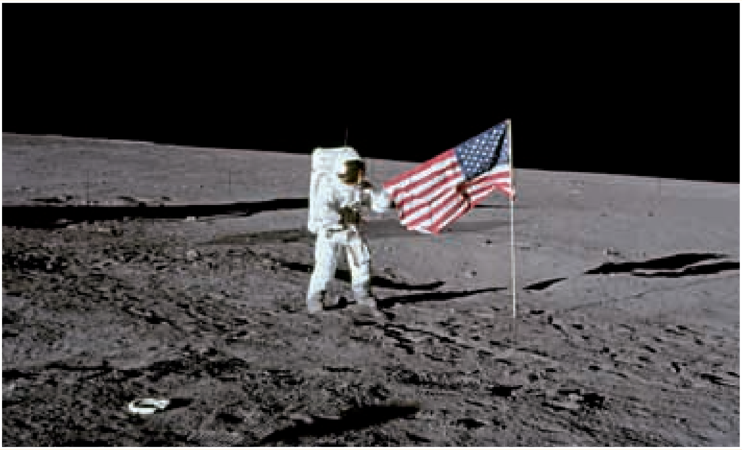
facing rendezvous windows.

In terms of hardware to power the contraption, five silver/zinc-oxide batteries provided power after the CSM detached – three for re-entry and after landing and two for vehicle separation and parachute deployment. It also had twelve 420 N nitrogen tetroxide/hydrazine reaction control thrusters. Basically, it was the Command Module that provided the re-entry capability at the end of the mission after separation from the Service Module.

The Service Module itself was a cylinder measuring 3.9 metres in diameter and 7.6 metres long, which was attached to the back of the CM. The outer skin of the SM was formed of 2.5-centimetre-thick aluminium honeycomb panels. The interior was divided by milled aluminium radial beams into six sections around a central cylinder. At the back of the SM was a liquid propellant 91,000 N engine and cone shaped engine nozzle. Attitude control was provided by four identical banks of four 450 N reaction control thrusters, each spaced 90 degrees apart around the front.

The six sections of the SM held three 31-cell hydrogen oxygen fuel cells which provided 28 volts, two cryogenic oxygen and two cryogenic hydrogen tanks, four tanks for the main propulsion engine, two for fuel and two for oxidizer, and the subsystems the main propulsion unit. Two helium tanks were mounted in the central cylinder. Electrical power system radiators were at the top of the cylinder and environmental control radiator panels spaced around the bottom.

The Lunar Module – the last component of an Apollo spacecraft – was the part that would detach in lunar orbit and proceed to land on the moon. Since this aspect has to also do with lunar exploration, we'll take a look at it in the next chapter.



MAN ON THE MOON

"That's one small step for man, one giant leap for mankind"

Like with any momentous achievement in the history of mankind, the Apollo program had its share of setbacks as well.

By the time the scientists got around to testing its flights, US President Kennedy had long been dead, killed in an assassination. But out of his memory and ambition to put a man on the moon, the Apollo programme got a further boost in funding as well as public support.

And then there was the Apollo 1 tragedy...

Apollo 1

On January 27, 1967, the Apollo launch team was hard at work at Launch

Pad 34 on Cape Canaveral. A full dress rehearsal was in progress for the Apollo 1 mission, the first manned mission in the Apollo Program, set for take-off on February 21.

NASA astronauts Gus Grissom, Edward White and Roger Chaffee were strapped in their seats in their command module atop a Saturn IB rocket. Their mission would test this new spacecraft in Earth orbit. All future Apollo crews would rely on this capsule to see them safely on their journeys to and from the moon.

At 6:31 p.m., the unthinkable happened. One of the astronauts, Chaffee reported, "Fire, I smell fire." Two seconds later White was heard saying, "Fire in the cockpit." The fire spread throughout the cabin in a matter of seconds. The last crew communication ended 17 seconds after the start of the fire, followed by loss of all telemetry.

The Apollo hatch could only open inward and was held closed by a number of latches which had to be operated by ratchets. It was also held closed by the interior pressure, which was higher than outside atmospheric pressure and required venting of the command module before the hatch could be opened. It took at least 90 seconds to get the hatch open under ideal conditions. Because the cabin had been filled with a pure oxygen atmosphere at normal pressure for the test and there had been many hours for the oxygen to permeate all the material in the cabin, the fire spread rapidly and the astronauts had no chance to get the hatch open. Nearby technicians tried to get to the hatch but were repeatedly driven back by the heat and smoke. By the time they succeeded in getting the hatch open roughly five minutes after the fire started the astronauts had already perished, probably within the first 30 seconds, due to smoke inhalation and burns.

Astronauts (left to right) Gus Grissom, Ed White, and Roger Chaffee, pose in front of Launch Complex 34 which is housing their Saturn 1 launch vehicle

In the accident's aftermath, the NASA family was distraught but determined to honour their fallen colleagues.

Flight Director Gene Kranz told his team at the Manned Spacecraft Center in Houston: "From this day forward, Flight Control will be known by two words: 'tough' and 'competent.' 'Tough' means we are forever accountable for what we do or what we fail to do. 'Competent' means we will never take anything for granted."

The Apollo program was put on hold while an exhaustive investigation was made of the accident. It was concluded that the most likely cause was a spark from a short circuit in a bundle of wires that ran to the left and just in front of Grissom's seat. The large amount of flammable material in the cabin in the oxygen environment allowed the fire to start and spread quickly. A number of changes were instigated in the program over the next year and a half, including designing a new hatch which opened outward and could be operated quickly, removing much of the flammable material and replacing it with self-extinguishing components, using a nitrogen-oxygen mixture at launch, and recording all changes and overseeing all modifications to the spacecraft design more rigorously.

Apollo 2-10

Following the tragedy, NASA grew more cautious and went back to the basics. Two test rockets were fired without any personnel on board, just to check the abilities of the Saturn I launch vehicle. These were unofficially dubbed the Apollo 2 and Apollo 3.

Apollo 4 was the first unmanned mission in the programme, and used the modified Saturn V launch vehicle. It was fitted with a complete Command/Service Module and on November 9, 1967, it successfully blasted off from Cape Canaveral. The mission provided vital information on the need for dampening mechanisms at the launchpad to protect structures in its vicinity.

Thereafter, Apollo 5 was launched on January 22, 1968, and became the first test of the Lunar Module, followed quickly by the Apollo 6 unmanned flight which made the scientists confident enough to put astronauts in the next mission.

Apollo 7 would become the first manned mission since the tragic loss of Apollo 1. On Oct 11, 1968, the rocket took off carrying Walter Schirra Jr., Walter Cunningham and Donn Eisele. At five minutes, 54 seconds into the mission, Schirra Jr., the commander, reported, "She is riding like a dream." About ten minutes after launch, Apollo 7 reached the first stage of its journey, an orbital path 227 by 285 kilometers above Earth. The Apollo vehicle and the CSM performed superbly. Durability was shown for 10.8

days – longer than a journey to the moon and back. With few exceptions, the other systems in the spacecraft operated as they should.

The next flight, Apollo 8, would be the first time a manned mission went as far as the moon. Unofficially titled 'Around the Moon and Back', the spacecraft launched on December 21, 1968 carrying astronauts Frank Borman, James Lovell Jr. and William Anders. After reaching the Earth's orbit, they further boosted towards the moon. The mission also proved the first mid-course correction of a manned spacecraft. Apollo 8 finally reached lunar orbit, where the crew conducted necessary tests and also broadcast a Christmas message to television sets around the world.

Apollo 9 launched on March 3, 1969, into a 190-kilometre Earth orbit with Commander James McDivitt, Command Module Pilot David Scott and Lunar Module Pilot Russell Schweickart aboard. The primary objective of the mission was an Earth-orbital engineering test of the first crewed Lunar Module. The flight plan's top priority was the CSM and LM rendezvous and docking. This was performed twice – once while the LM was still attached to the Saturn rocket, and again when the LM was active.

Apollo 10 launched on May 18, 1969, with crew members Commander Thomas Stafford, Command Module Pilot John Young and Lunar Module Pilot Eugene Cernan. The launch trajectory had been so satisfactory that only one of four midcourse corrections was needed.

The Apollo 10 mission encompassed all aspects of an actual crewed lunar landing, except the landing. It was the first flight of a complete, crewed Apollo spacecraft to operate around the moon. Objectives included a scheduled eight-hour lunar orbit of the separated Lunar Module and descent to about 15 kilometres off the moon's surface before ascending for rendezvous and docking with the Command and Service Module. Pertinent data to be gathered in this landing rehearsal dealt with the lunar potential, or gravitational effect, to refine the Earth-based crewed spaceflight network tracking techniques, and to check out LM programmed trajectories and radar, and lunar flight control systems. Twelve television transmissions to Earth were planned, including the first colour TV pictures to Earth of the moon's surface. All mission objectives were achieved.

Apollo 11

With every aspect of the programmes tested, it was now time for NASA to embark on its most ambitious mission yet: an actual landing on the moon.

Apollo 11 launched from Cape Canaveral on July 16, 1969, carrying Com-

mander Neil Armstrong, Command Module Pilot Michael Collins and Lunar Module Pilot Edwin "Buzz" Aldrin into an initial Earth-orbit of 186 kilometres. The Command and Service Module of the spacecraft was codenamed Columbia, while the Lunar Module was called 'Eagle'.

Astronauts (left to right) Neil Armstrong, Michael Collins and Edwin "Buzz" Aldrin pose before the launch

Two hours, 44 minutes and one-and-a-half revolutions after launch, they reignited for a second burn to place the spacecraft into a translunar orbit.

The first colour TV transmission to Earth from Apollo 11 occurred during the translunar coast of the CSM/LM. Later, on July 17, a three-second burn of the SPS was made to perform the second of four scheduled midcourse corrections programmed for the flight. The launch had been so successful that the other three were not needed.

On July 18, Armstrong and Aldrin put on their spacesuits and climbed through the docking tunnel from Columbia to Eagle to check out the LM, and to make the second TV transmission.

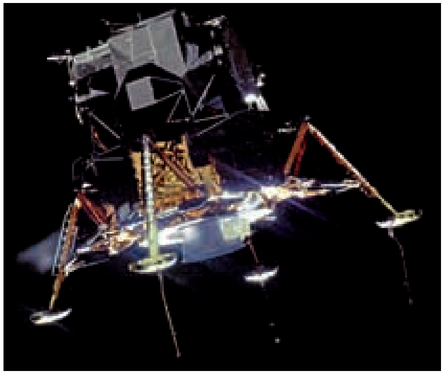
On July 19, after Apollo 11 had flown behind the moon out of contact with Earth, they performed lunar orbit insertion manoeuvres that put them in a closer elliptical orbit of the moon at 111 kilometres to 300 kilometres from the surface.

On July 20, Armstrong and Aldrin entered the Lunar Module again, made a final check, and at 100 hours, 12 minutes into the flight, the Eagle undocked and separated from Columbia.

The Eagle

The Lunar Module was a two-stage vehicle designed for space operations near and on the Moon. The spacecraft mass of 15,065 kg was the mass of the LM including astronauts, propellants and expendables.

The Eagle was divided into two parts: the ascent stage and the descent stage. Basically, the two units would go to the moon together as one device, but only the


The Apollo 11 Lunar Module Eagle, in a landing configuration, photographed from the CSM by astronaut Michael Collins

ascent stage would go back to rendezvous and dock into the CSM of the Apollo 11.

The descent stage comprised the lower part of the spacecraft and was an octagonal prism 4.2 metres across and 1.7 metres thick. It served as a platform for launching the ascent stage and was left behind on the Moon.

The unit contained the landing rocket, two tanks of aerozine 50 fuel, two tanks of nitrogen tetroxide oxidizer, water, oxygen and helium tanks and storage space for the lunar equipment and experiments. The engine was a deep-throttling ablative rocket with a maximum thrust of about 45,000 N mounted on a gimbal ring in the center of the descent stage.

Four landing legs with round footpads were mounted on the sides, which held the bottom of the stage about 1.5 metres above the surface. One of the legs had a small astronaut egress platform and ladder. A one-metre long conical descent engine skirt protruded from the bottom of the stage. The descent stage dry mass was 2034 kg and 8212 kg of propellant were onboard initially.

The ascent stage was an irregularly shaped unit approximately 2.8 m high and 4.0 by 4.3 meters in width mounted on top of the descent stage. It was launched from the Moon at the end of lunar surface operations and returned the astronauts to the CSM.

The ascent stage housed the astronauts in a pressurized crew compartment with a volume of 6.65 cubic meters which functioned as the base of operations for lunar operations. There was an ingress-egress hatch in one side and a docking hatch for connecting to the CSM on top, next to a radar antenna for the rendezvous. Two triangular windows were above and to either side of the egress hatch and four thrust chamber assemblies were mounted around the sides. An environmental control system recycled oxygen and maintained temperature in the electronics and cabin. There were no seats in the LM. A control console was mounted in the front of the

crew compartment above the ingress-egress hatch and between the windows and two more control panels mounted on the side walls.

At the base of the assembly was the ascent engine – a fixed, constant-thrust rocket with a thrust of about 15,000 N. The stage also contained an aerozine 50 fuel and an oxidizer tank, and helium, liquid oxygen, gaseous oxygen, and reaction control fuel tanks. The dry mass of the ascent stage was 2180 kg and it held 2639 kg of propellant.

One small step...

At 20:17:40 on July 20, 1969, partially piloted manually by Armstrong, the Eagle landed in the Sea of Tranquility at 0.6741 degrees N latitude, 23.4730 degrees E longitude. Armstrong's calm voice came over the radio, "Houston, Tranquility Base here – the Eagle has landed."

After a short rest period, Armstrong stepped onto the lunar surface at 02:56:15 on July 21, stating, "That's one small step for man, one giant leap for mankind."He then collected a small contingency sample of lunar material.

Aldrin followed 19 minutes later, calling the lunar surface "magnificent desolation". The astronauts then unveiled the plaque mounted on a strut behind the ladder and read the inscription aloud: "Here men from the planet Earth first set foot on the Moon, July 1969, A.D. We came in peace for all mankind." They put up an American flag and talked to President Nixon by radiotelephone.

During the EVA, in which they both ranged up to 100 metres from the Eagle, Aldrin deployed the Early Apollo Scientific Experiments Package, or EASEP, experiments.

The EASEP consisted of a set of scientific instruments emplaced at the Apollo 11 landing site by the astronauts. This package was the forerunner of the ALSEP (Apollo Lunar Surface Scientific Experiments Package) used on the later Apollo missions. It consisted of two solar panels to provide power (the EASEP could only operate during lunar day), an antenna and communications system to send data to Earth ground stations and receive commands, a passive seismometer, designed to measure seismic activity and physical properties of the lunar crust and interior, and a lunar dust detector, to measure dust accumulation and radiation damage to solar cells.

The whole contraption comprised a square base on which was mounted the seismometer and dust detector, along with an isotope heater and cylindrical antenna mast with an antenna positioning mechanism. Two brackets protruded from opposite sides of the base and held the canted rectangular

solar panels, positioned to face towards the east and west. The unit had a total mass of 48 kg.

The EASEP was deployed approximately 17 metres south of the Eagle, and was turned on by ground command while the astronauts were still on the surface. About 5 hours before local lunar sunset on August 3, 1969 – well after the astronauts had left – transmission was stopped by ground command when the power began to drop as predicted. Despite operating temperatures which exceeded the planned maximum, the EASEP functioned normally. The instrument was turned on again on the next lunar day but on August 27, 1969, near noon of this second lunar day, the EASEP no longer accepted commands from Earth stations and the experiment was terminated.

Buzz Aldrin poses for what is arguably the most famous photo of man on the moon. In his visor, you can see a reflection of Neil Armstrong clicking the photograph

After taking two core tube samples of lunar soil, Aldrin returned to the LM first, after 1 hour 41 minutes on the lunar surface. Armstrong followed about 12 minutes later, after transferring the sample boxes up to Aldrin and placing a packet of memorial items on the ground. The duo spent the next seven hours resting and checking out systems.

The Eagle lifted off from the moon at 17:54:01 on July 21, after 21 hours, 36 minutes on the lunar surface. After docking with the CSM, the Eagle was jettisoned into lunar orbit. The fate of the LM is not known, but it's assumed to have crashed into the lunar surface sometime in the following few months.

The journey back began on July 21, and after successfully leaving the lunar orbit, the astronauts slept for about 10 hours. After a small midcourse correction, re-entry procedures into Earth were initiated on July 24 – 44 hours after leaving lunar orbit.

The Service Module separated from the Command Module, which was re-oriented to a heat-shield-forward position. Deploying its parachute after a flight of 195 hours, 18 minutes, 35 seconds, Apollo 11 splashed down in the Pacific Ocean and Armstrong, Aldrin and Collins received a hysterical welcome from everyone on Earth.

Apollo 12-17 and cancellation

Following the success of the Apollo 11 mission in stamping the supremacy of the American space programmed, NASA wasted no time in sending more astronauts to the moon.

On November 14, 1969, Apollo 12 took off with Charles Conrad, Alan Bean and Richard Gordon on board. Everything went off successfully and on November 19, Conrad and Bean became the third and fourth men to step on the moon, respectively.

In their first lunar exploration, Conrad spent 3 hours, 39 minutes outside the Lunar Module, and Bean logged 2 hours, 58 minutes. During this EVA, Conrad collected lunar surface samples and deployed both the S-band communication antenna and the solar wind experiment. The new Apollo Lunar Surface Scientific Experiments Package (ALSEP) was deployed within an arc of 600 to 700 feet of the LM. The ALSEP functioned satisfactorily, except for two items in the package, and was expected to yield data for up to two years.

Throughout this first EVA, Conrad and Bean also took photographs of the experiment equipment, the spacecraft, the lurain (lunar terrain) and of themselves. Before entering the Intrepid, Bean took a 16-inch-deep core sample of the lunar surface and was followed back into the LM by Conrad. The second EVA included the collection of 70 pounds of rock and dirt samples, the retrieval of 10 to 15 pounds of randomly selected samples and further probing of two areas to retrieve lunar material from depths up to 32 inches below the surface. The most important part of this second EVA was a 5,200-foot traverse of the lurain, ranging up to 1,300 feet from the LM.

On November 20, they departed to rendezvous with the CSM and the Apollo 12 crew returned home without any glitches on November 24.

Apollo 13, launched on April 11, 1970, was the only flight after Armstrong's historic journey that had a problem and didn't land on the moon. After reaching lunar orbit, astronauts James Lovell, Fred Haise and John Swigert aborted their mission upon detecting a rupture in the Service Module oxygen tank. This would be the point where Swigert uttered the

now-famous phrase, "Houston, we've had a problem here." The full series of events that followed was nothing short of a Hollywood script – and in fact, was made into a movie starring Tom Hanks – in which the astronauts had to make an emergency move to the Lunar Module and use it to reach Earth safely on April 17, 1970, braving dehydration, lack of oxygen and other extreme circumstances.

NASA went into overdrive fixing the issues and on January 31, 1971, Apollo 14 took off carrying Alan Shepard, Edgar Mitchell and Stuart Roosa. After landing on the moon on February 5, Shepard and Mitchell conducted two EVAs, collecting 42 kgs of rocks and soil for return to Earth, which would be distributed among 16 countries for tests and analysis. Shepard, the first American to perform an EVA in space, also set a new distance-travelled record on the lunar surface of approximately 9,000 feet. On February 9, the Apollo 14 crew landed safely back on Earth without any incident.

Launched on July 26, 1971, Apollo 15 was the first of the Apollo "J" missions capable of a longer stay time on the moon and greater surface mobility. Apart from Alfred Worden, the crew included David Scott and James Irwin who would become the 7th and 8th person to walk on the moon on July 31.

Over three days, the duo explored the moon more than any of their predecessors. Exploration and geological investigations were enhanced by the addition of the Lunar Roving Vehicle (more details about which will be in the next sub-chapter). Scott and Irwin completed a record 18 hours, 37 minutes of exploration, travelled 17.5 miles in the first car that humans have ever driven on the moon, collected more than 170 pounds of lunar samples, set up the ALSEP array, obtained a core sample from about 10 feet beneath the lunar surface, and provided extensive oral descriptions and photographic documentation of geologic features in the vicinity of the landing site.

Before returning to Earth, however, there was another mission: the launching of a Particles and Fields subsatellite into lunar orbit by the Command and Service Module. The subsatellite was designed to investigate the moon's mass and gravitational variations, particle composition of space near the moon and the interaction of the moon's magnetic field with that of Earth. After completing this subsatellite mission successfully, Apollo 15 returned to Earth on August 7, 1971.

John Young, Charles Duke and Thomas Mattingly formed the crew of Apollo 16, which blasted off from Earth on April 16, 1972. The Lunar Module carrying Young and Duke touched down on the moon on April 21. In


Astronaut Eugene Cernan takes a stripped-down version of the Lunar Roving Vehicle for a spin before it is loaded up with gadgetry.

non-scientific terms, their EVAs aboard the Lunar Roving Vehicle and on foot weren't too distinctive from previous missions (collective samples, taking measurements, etc.) and after 71 hours on the lunar surface, they returned to the spacecraft. After launching another Particles and Fields subsatellite, they charted a course for Earth and landed safely on April 27.

On December 7, 1972, the last of the Apollo spacecrafts took off from Cape Canaveral. The crew of the Apollo 17 comprised Eugene Cernan, Harrison Schmitt and Ronald Evans. On December 11, Cernan and Schmitt landed their Lunar Module on the moon. Over the next three days, they conducted several experiments in three EVAs, lasting a total of just over 22 hours. Leaving to dock back with their Command and Service Module, Cernan became the last man to walk on the moon. Apollo 17 made an incident-free journey back to Earth, landing on December 17.

Although three more missions were planned by NASA, they would never be executed. After firmly establishing the supremacy of the USA in the space programme by becoming the only nation to have landed a man on the moon, NASA cancelled the Apollo programme after Apollo 17 returned. The final cost of Project Apollo was reported as $25.4 billion – an exorbitant sum back in 1973. NASA estimates that in modern terms, that would be roughly around $170 billion based on the US dollar value in 2005.

Lunar Roving Vehicle

The Lunar Roving Vehicle (LRV) was an electric vehicle designed to operate in the low-gravity vacuum of the moon and to be capable of traversing the lunar surface, allowing the Apollo astronauts to extend the range of their surface extravehicular activities.

As mentioned earlier, three LRVs were driven on the Moon:

- **Apollo 15:** David Scott and Jim Irwin drove a total of 27.8 km in 3 hours, 2 minutes. The longest single traverse was 12.5 km and the maximum range from the LM was 5.0 km.
- **Apollo 16:** John Young and Charles Duke drove 26.7 km in 3 hours 26 minutes of driving. The longest traverse was 11.6 km and the LRV reached a distance of 4.5 km from the LM.
- **Apollo 17:** Gene Cernan and Harrison Schmitt drove 35.9 km in 4 hours 26 minutes. The longest traverse was 20.1 km and the greatest range from the LM was 7.6 km.

The Lunar Roving Vehicle had a mass of 210 kg and was designed to hold a payload of an additional 490 kg on the lunar surface. The frame was 3.1 metres long with a wheelbase of 2.3 metres. The maximum height was 1.14 meters. The frame was made of aluminium alloy and consisted of a 3-part chassis which was hinged in the centre so it could be folded up and hung in the Lunar Module quad 1 bay. It had two side-by-side foldable seats made of tubular aluminium with nylon webbing and aluminium floor panels. An armrest was mounted between the seats, and each seat had adjustable footrests and a Velcro seatbelt. A large mesh dish antenna was mounted on a mast on the front centre of the rover. The suspension consisted of a double horizontal wishbone with upper and lower torsion bars and a damper unit between the chassis and upper wishbone. Fully loaded, the LRV had a ground clearance of 14 inches.

The wheels consisted of a spun aluminium hub. The tires were made out of zinc-coated woven steel, measuring 32 inches in diameter and 9 inches wide. Inside the tire was a 25-inch-diameter bump stop frame to protect the hub. Dust guards were mounted above the wheels. Each wheel had its own electric drive and a mechanical brake unit. Manoeuvring capability was provided through the use of front and rear steering motors. Each series wound DC steering motor was capable of 0.1 hp. Both sets of wheels would turn in opposite directions, giving a steering radius of 3.1 metres, or could be decoupled so only one set would be used for steering.

Power was provided by two 36-volt silver-zinc potassium hydroxide non-rechargeable batteries. These were used to power the drive and steering motors and also a 36 volt utility outlet mounted on front of the LRV to power the communications relay unit or the TV camera. Passive thermal controls kept the batteries within an optimal temperature range.

A T-shaped hand controller situated between the two seats controlled the four drive motors, two steering motors and brakes. Moving the stick forward powered the LRV forward; left and right turned the vehicle left or

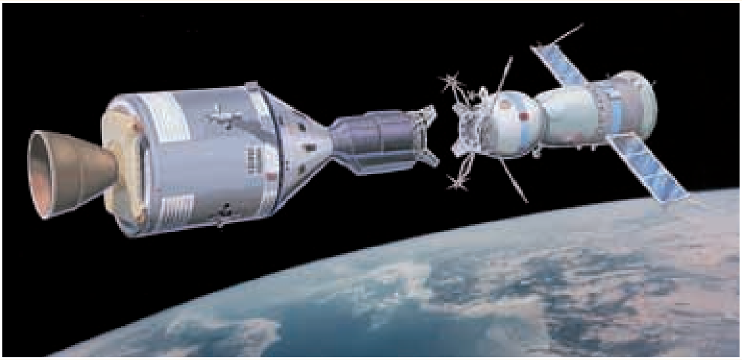
right; and pulling backwards activated the brakes. Activating a switch on the handle before pulling back would put the LRV into reverse. Pulling the handle all the way back activated a handbrake.

The control and display modules were situated in front of the handle and gave information on the speed, heading, pitch, and power and temperature levels. Navigation was based on continuously recording direction and distance through use of a directional gyro and odometer, and inputting this data to a computer which would keep track of the overall direction and distance back to the LM. There was also a Sun-shadow device which could give a manual heading based on the direction of the Sun, using the fact that the Sun moved very slowly in the sky.

The LRV was deployed using a system of pulleys and braked reels using ropes and cloth tapes. The rover was folded and stored in quad 1 with the underside of the chassis facing out. One astronaut would climb the egress ladder on the Lunar Module and release the rover, which would then be slowly tilted out by the second astronaut on the ground through the use of reels and tapes. As the rover was let down from the bay, most of the deployment was automatic. The rear wheels folded out and locked in place and when they touched the ground the front of the rover could be unfolded, the wheels deployed, and the entire frame let down to the surface by pulleys. The rover components locked into place upon opening. Cabling, pins, and tripods would then be removed and the seats and footrests would be raised. After switching on all the electronics, the vehicle was ready to back away from the Lunar Module.

A total of four lunar rovers were built, one each for Apollos 15, 16 and 17, and one that was used for spare parts after the cancellation of further Apollo missions. The LRV was developed in only 17 months and yet performed all its functions on the Moon with no major anomalies.

Harrison Schmitt of Apollo 17 said, “The Lunar Rover proved to be the reliable, safe and flexible lunar exploration vehicle we expected it to be. Without it, the major scientific discoveries of Apollo 15, 16, and 17 would not have been possible; and our current understanding of lunar evolution would not have been possible.”



THE END OF THE SPACE RACE

What went wrong with the Soviet's plans of going to the moon and how they finally joined hands with their Cold War rival, the US

When Neil Armstrong took his historic first step on the moon on July 20, 1969, the USA had officially won the space race to the moon. But it does beg one very important question: what went so wrong so quickly with the Soviet Space Programme?

The Soviets were ahead of the Americans in every aspect of space research, beating them in launching the first artificial satellite, the first man into space and even conducting the first spacewalk. So how did they go from there to a state where they never managed to put a man on the moon at all?

A Fragmented Soviet Space Programme

If you look at the history of space programmes, and especially at the Space Race, a pattern becomes apparent. In the late 1940s and throughout the 1950s, the Americans were fragmented into several different factions, each trying their own methods and approaches to the problems of space technology. The Soviets, on the other hand, were more or less unified under the guidance of Sergei Korolev, the chief designer.

In the 1960s, though, this turned around on its head very quickly. The formation of NASA provided the US space programmes with the unified leadership that it sorely missed in the early stage of the Space Race. And under James Webb, the programme flourished like never before.

The Soviets, on the other hand, went the opposite way. Korolev's initial successes still put him at the top of the chain, but the general public's interest in space meant that it became an internal political hotspot. Rival designers started biting at Korolev's heels and taking away important projects by aligning themselves with different political representatives. As the internal political scenario of the Communist Party started deteriorating, so did the ability of the Soviet Space Programme to work with unified guidance.

Sergei Korolev, the chief scientist of the Soviet Space Programme

A prime example of this is that of Vladimir Chelomei. The Ukranian rocket engineer enjoyed the patronage of Soviet Premier Nikita Khrushchev and was given the prestigious projects of a manned moon mission and a manned space station, at a time when Korolev was much further ahead in that field. Chelomei's area of expertise had always been developing rockets, not the understanding of space, and this meant that he started from scratch with a group of scientists isolated from the research of Korolev and his group.

Another problem with the scenario was that while the Kennedy had announced his intention of putting a man on the moon by the end of the decade, it wasn't something that terribly interested Korolev. Emotionally, he did have a desire to beat the Americans, but scientifically, he had much grander projects in mind. Specifically, Korolev had been working extensively on a project to send manned missions to Mars and Venus, thus asserting

the USSR's supremacy in space by being the first interplanetary explorers. As early as 1964, Korolev had drawn up detailed plans on how to make this dream a reality through the use of innovative spacecraft and a revolutionary life support system. Indeed, Korolev was far ahead of his time and some of his work is still valid and used today.

However, despite such internal bickering among the Soviets, they did manage some incredible feats in this time. Indeed, it could well be argued that apart from the 'Moon Race', the Soviets won every aspect of the Space Race, including the first Extra Vehicular Activity, the first lunar probe and more.

Korolev was still involved in different aspects of the space programme and after his successful Vostok missions, he started developing plans for the Soyuz spacecraft which would eventually carry Russian astronauts to the moon. However, Soyuz was a good three years away from being operational, and as a stop-gap appeasement, he modified the existing Vostok to form the new Voskhod spacecraft, which would be the first multi-person flight into space as well as the first time cosmonauts travelled without spacesuits.

Joint NASA-SSP Moon Project

After Kennedy had committed to the Apollo programme of putting a man on the moon, the estimated budgetary costs – along with the actual feasibility of the project within the given timeline – started weighing on his mind. The challenge wasn't just to get to the moon, it was also to get there before the Soviets, who had beaten the US at every part of the Space Race so far.

Kennedy and Khrushchev enjoyed a special relationship that premiers of the two countries hadn't had since before World War II. It wasn't that they were friends, but through repeated meetings and conversations, a trust had started to form, according to Khrushchev's son who would recount these events later.

At the 1963 United States General Assembly, Kennedy laid down an audacious proposal of a joint space programme between the USA and the USSR to send man to the moon:

"In a field where the United States and the Soviet Union have a special capacity – in the field of space – there is room for new cooperation, for further joint efforts in the regulation and exploration of space. I include among these possibilities a joint expedition to the moon. Space offers no problems of sovereignty; by resolution of this Assembly, the members of the United Nations have foresworn any claim to territorial rights in outer space or on celestial bodies, and declared that international law and the United

USSR Premier Nikita Khrushchev and US President John F. Kennedy

Nations Charter will apply. Why, therefore, should man's first flight to the moon be a matter of national competition? Why should the United States and the Soviet Union, in preparing for such expeditions, become involved in immense duplications of research, construction, and expenditure? Surely we should explore whether the scientists and astronauts of our two countries – indeed of all the world – cannot work together in the conquest of space, sending someday in this decade to the moon not the representatives of a single nation, but the representatives of all of our countries."

The proposal was met with applause in the Assembly, but Khrushchev was quick to dismiss it. However, his son later recounted that the Soviet Premier was considering it in late 1963, when Kennedy was assassinated.

Khrushchev did not enjoy the same rapport or trust with Kennedy's successor, President Lyndon Johnson, and abandoned the plans.

Another Upheaval

In 1964, there was another shake-up in the Soviet political scenario and Khrushchev was removed from power. The repercussions of this were felt strongly in the Soviet Space Programme as Chelomei was finally told to cede his moon programme to Korolev, who was once again put in charge of all projects in the SSP. And there was a new objective of getting to Earth's natural satellite by 1967 – the 50th anniversary of the Communist Revolution.

The first step, of course, was to stop the work on the Vostok and Voskhod spacecrafts, which were deemed to be not good enough for a trip to the moon. For two years, Korolev worked tirelessly on the lunar programme, coming up with the Soyuz spacecraft that would eventually become history's most efficient man-made machine for space travel.

However, the Soviet Space Programme suffered another major setback on January 14, 1966, when Korolev died in surgery due to medical complications. With this singular visionary lost, the SSP once again faced internal fighting among the many space designers.

Rocket scientist Vasili Mishin was given the official task of taking over the programme, which newspapers around the world had started to call the 'Moonshot'.

Moonshot

Although Mishin took over the programme in 1966, he did not enjoy the support of his superiors nor his colleagues in the same way that Korolev did. Due to this, the infighting continued and ate into his timeline of delivering on what he was asked to do.

For the lunar mission itself, Mishin decided to continue with Korolev's vision of the Soyuz spacecraft. A lunar excursion flyby was planned for 1967 and the first test of the Soyuz spacecraft itself was scheduled for April of that year.

Korolev's original plan for the flyby was called the Soyuz A-B-V circumlunar complex, in which the Soyuz spacecraft (carrying two cosmonauts) would rendezvous with two other components – a booster (for propulsion) and a tanker (for fuel) – in Earth's orbit. These components, of course, would be launched via rockets. The resultant vehicle would be capable of making a flyby of the moon and then returning to Earth's orbit again. Here, the cosmonauts would once again disassemble the Soyuz from its two added components and make their way back to earth in the Soyuz spacecraft alone.

Soyuz

The Soyuz spacecraft was initially designed to carry two cosmonauts at a time, but was later expanded to accommodate three passengers. It consists of an Orbital Module, a Descent Module and an Instrumentation/Propulsion Module.

i)Orbital Module – This portion of the Soyuz spacecraft is used by the crew while on orbit. It has a volume of 230 cubic feet, with a docking mecha-

The Soyuz Spacecraft in flight

nism, hatch and rendezvous antennas located at the front end.

The rendezvous antennas are used by the automated docking system – a radar-based system – to manoeuvre the vehicle towards desired objectives. In the future, a window would be added to this the module.

The opposite end of the Orbital Module connects to the Descent Module via a pressurized hatch. Before returning to Earth, the Orbital Module separates from the Descent Module – after the de-orbiting manoeuvre – and burns up upon re-entry into the atmosphere.

ii)Descent Module – The Descent Module is where the cosmonauts sit for launch, re-entry and landing. All the necessary controls and displays of the Soyuz are located here. The module also contains life support supplies and batteries used during descent, as well as the primary and backup parachutes and landing rockets.

It also contains custom-fitted seat liners for each crew-member's couch/seat, which are individually moulded to fit each person's body – this ensures a tight, comfortable fit when the module lands on the Earth.

The module has a peri-

scope, which allows the crew to view the docking target. The eight hydrogen peroxide thrusters located on the module are used to control the spacecraft's orientation, or attitude, during the descent until parachute deployment. It also has a guidance, navigation and control system to manoeuvre the vehicle during the descent phase of the mission.

This module weighs 2900 kilograms, with a habitable volume of 141 cubic feet. Approximately 50 kgs of payload can be returned to Earth in this module and up to 150 kgs if only two crewmembers are present. The Descent Module is the only portion of the Soyuz that survives the return to Earth.

iii)Instrumentation/Propulsion Module – This module contains three compartments: Intermediate, Instrumentation and Propulsion.

The intermediate compartment is where the module connects to the Descent Module. It also contains oxygen storage tanks and the attitude control thrusters, as well as the electronics, communications and control equipment. The primary guidance, navigation, control and computer systems of the Soyuz are in the instrumentation compartment, which is a sealed container filled with circulating nitrogen gas to cool the avionics equipment.

The propulsion compartment contains the primary thermal control system and the Soyuz radiator, which has a cooling area of 86 square feet. The propulsion system, batteries, solar arrays, radiator and structural connection to the Soyuz launch rocket are located in this compartment.

The propulsion compartment contains the system that is used to perform any manoeuvres while in orbit, including any rendezvous and the de-orbit burns necessary to return to Earth. The propellants are nitrogen tetroxide and unsymmetric-dimethylhydrazine. The main propulsion system and the smaller reaction control system, used for attitude changes while in space, share the same propellant tanks.

The two Soyuz solar arrays are attached to either side of the rear section of the Instrumentation/Propulsion Module and are linked to rechargeable batteries. Like the Orbital Module, the intermediate section of the Instrumentation/Propulsion Module separates from the Descent Module after the final deorbit maneuver and burns up in atmosphere upon re-entry.

Flights, Casualties and the End of Moonshot

On April 23, 1967, Soyuz 1 was launched into orbit. But a major controversy surrounds this particular launch, as it was suggested in the book Starman by Jamie Doran and Piers Bizony that Mishin and others knew it was not ready for flight and was a doomed mission. However, political pressure

demanded that it be carried forward lest the Americans achieve the target of a moon mission first.

Vladimir Komarov, the pilot aboard the Soyuz 1, was apparently adamant of going because the backup commander was his closest friend, Russian hero Yuri Gagarin, the first man in space. Gagarin had himself inspected the Soyuz 1 a while before the launch and sent a 10-page memo to authorities about its many fallacies and why it wouldn't work.

Sure enough, Komarov's spacecraft encountered several problems and fell back to Earth, killing the cosmonaut. The Soviet Space Programme never really recovered from this tragedy and delayed further plans to send cosmonauts to the moon, despite the successful launches of Soyuz 2 to Soyuz 10. Soyuz 11 saw another technical problem that killed three cosmonauts on board.

Eventually, once it became evident that the Americans had won the Moon Race, the Moonshot was unofficially scrapped, although work would continue on it well into the 1970s. The Soviets were well and truly behind in the Space Race now, but the introduction of the Soyuz spacecraft would remain the most significant technological advance from this period, as it would prove to be the most efficient spacecraft in history – used to this day on the International Space Station.

The Apollo-Soyuz Mission

By the mid-70s, things had changed. The US had won the race to the Moon, with six Apollo landings between 1969 and 1972. Both nations had launched space stations, the Russian Salyut and American Skylab. With the Space Shuttle still a few years off and the diplomatic chill thawing, the time was right for a joint mission.

The Apollo-Soyuz Test Project would send NASA astronauts Tom Stafford, Deke Slayton and Vance Brand in an Apollo Command and Service Module to meet Russian cosmonauts Aleksey Leonov and Valeriy Kubasov in a Soyuz capsule. A jointly designed, US-built docking module fulfilled the main technical goal of the mission, demonstrating that two dissimilar craft could dock in orbit. But the human side of the mission went far beyond that.

On July 17, 1975, the five explorers and the two craft – launched two days before – approached each other for docking. As Stafford guided the Apollo forward, Soyuz commander Leonov quipped, "Tom, please don't forget about your engine." With a live TV audience watching, the two craft finally met: "Soyuz and Apollo are shaking hands now."

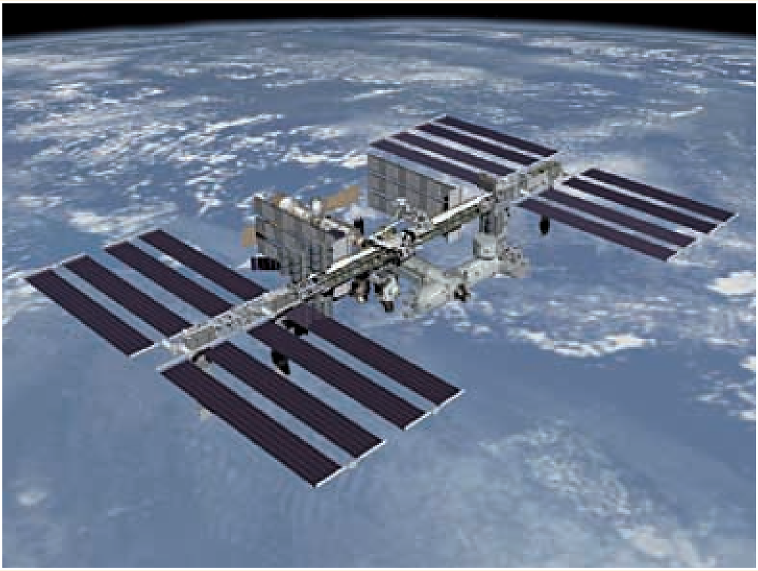
The Apollo Soyuz Test Project Crew Deke Slayton, Thomas Stafford, Vance Brand, Alexei Leonov, Waleri Kubassov

A few hours later it was the crew members who were literally shaking hands, exchanging hugs and ceremonial gifts, including US, Soviet and United Nations flags, commemorative plaques, medallions, certificates and tree seeds.

The crews received a congratulatory message from Soviet premier Leonid Brezhnev and a phone call from US President Gerald Ford.

Apollo Commander Stafford had another unique cultural exchange for the cosmonauts. He'd gotten country music star Conway Twitty to record 'Privet Radost', a Russian version of his hit 'Hello, Darlin'. About an hour before the two craft undocked, the song was played from orbit and heard all over the world.

The Apollo crew returned to Earth on July 19, and their Russian counterparts two days later. It would be two decades until the countries teamed up again with the Shuttle-Mir program, but the seed was planted. As Brand said, "I really believe that we were sort of an example ... to the countries. We were a little of a spark or a foot in the door that started better communications." d



SPACE STATIONS

Mankind's first attempt at colonising the great beyond

The moment Yuri Gagarin was stably operating his spacecraft in Earth's orbit, the imagination of every scientist went into overdrive about the possibilities of space exploration. And of course, at the forefront of this was some sort of habitable machine that would let cosmonauts and astronauts spend time in space.

While Korolev was preoccupied with the Moon Race after taking the project back from Chelomei, the latter wasn't sitting around twiddling his thumbs. Using his expertise, he started working on the possibility of setting up a space station for scientific research, military strategies and a platform for future space explorations.

Salyut

Chelomei and his staff developed a military station for two to three cosmonauts, with a design life of 1 to 2 years. They designed an integrated system: a single-launch space station dubbed Almaz ("diamond") and a Transport Logistics Spacecraft for reaching it. Chelomei's three-stage Proton booster would launch them both.

Almaz was to be equipped with a crew capsule, radar remote-sensing apparatus for imaging the Earth's surface, cameras, two re-entry capsules for returning data to Earth, and an anti-aircraft cannon to defend against American attack. It would be the world's first military space station.

However, when NASA announced it was also working on a space station – Skylab – the Soviets sought to speed up the launch by taking Chelomei's research and handing it to the group formerly headed by Korolev, given their success with the Soyuz spacecraft. The space station was renamed Salyut ("salute") and Salyut 1 was successfully launched on April 19, 1971,

A model of the Salyut space station

becoming the first space station to orbit Earth. It used a "monolithic" design, which meant that it was completely constructed and assembled on Earth and then launched into space.

The purpose of Salyut was to test the elements of the systems of a space station and to conduct scientific research and experiments. The craft was being 20 metres in length, 4 metres in maximum diameter, and 99 cubic cm in interior space. Of its several compartments, three were pressurized (100 cubic m total), and two could be entered by the crew.

The first, or transfer, compartment was connected directly with Soyuz 11 – the first spacecraft to successfully board the space station (Soyuz 10 could not enter Salyut due to a mechanical error). Its docking cone had a 2-metre front end diameter. The second and main compartment was about 4 metres in diameter. Televised views showed enough space for eight big chairs (seven at work consoles), several control panels, and 20 portholes (some unobstructed by instruments). The third pressurized compartment contained the control and communications equipment, the power supply, the life support system, and other auxiliary equipment. The fourth, and final, compartment (unpressurized) was about 2 metres in diameter and contained the engine installations and associated control equipment.

Salyut had buffer chemical batteries, reserve supplies of oxygen and water, and regeneration systems. Externally mounted were two double sets of solar cell panels that extended like wings from the smaller compartments at each end, the heat regulation system's radiators, and orientation and control devices.

The Soyuz 11 crew transferred to Salyut on June 7, 1971 and their mission was announced as (1) checking and testing the design, units, onboard systems, and equipment of the orbital piloted station, (2) trying out the methods and autonomous means of the station's orientation and navigation, as well as the systems for controlling the space complex while manoeuvring in orbit, (3) studying geological-geographical objects on the earth's surface, atmospheric formations, and the snow and ice cover of the earth, (4) studying physical characteristics, processes, and phenomena in the atmosphere and outer space in various ranges of the spectrum of electromagnetic radiation, and (5) conducting medico-biological studies to determine the possibilities of performing various jobs by the cosmonauts in the station and study the influence of space flight factors on the human organism.

After flying 362 orbits docked with Salyut, the crew transferred back to Soyuz 11 on June 30, 1971. The mission ended in disaster when the crew capsule depressurized during preparations for re-entry, killing the three-man crew – Vladislav Volkov, Georgi Dobrovolski and Viktor Patsayev – and making them the only humans to die in space.

Salyut 1 was moved to higher orbits in July and August of 1971 to ensure that it would not end through early decay. On October 11, the Salyut engines were fired for the last time to lower its orbit and ensure prompt decay over the Pacific Ocean. After 175 days in space, the first real space station died.

Of course, this was just the demise of the first of the Salyut space stations.

The Salyut programme itself ran for many more years. Salyut 2, Salyut 3 and Salyut 5, which quickly followed, would be part of the military-oriented Almaz programme.

Salyut 6 would be the first major advance in the space station programme. It and the Salyut 7, which closely resembled its predecessor, would be known as 'second-generation' Soviet space stations.

On December 10, 1977, Yuri Romanenko and Georgi Grechko became the first crew to board the space station. On March 12, 1981 the last crew – Vladimir Kovalyonok and Viktor Savinyikh – arrived and stayed for 75 days.

With Salyut 6, the Soviet space station program evolved from short-duration to long-duration stays. It was launched unmanned and crews arrived later in Soyuz spacecraft. It had two docking ports. This permitted refuelling and resupply by automated spacecrafts. They docked automatically at the aft port, and were then opened and unlocked by cosmonauts on the station. Transfer of fuel to the station took place automatically under supervision from the ground.

A second docking port also meant long-duration resident crews could receive visitors. Visiting crews often included cosmonaut-researchers from Soviet bloc countries or countries sympathetic to the Soviet Union. Vladimir Remek of Czechoslovakia, the first space traveler not from the US or USSR, visited Salyut 6 in 1978.

An experimental transport logistics spacecraft called Cosmos 1267 docked with Salyut 6 in 1982, proving that large modules could dock automatically with space stations – a major step toward the multimodular Mir station and the International Space Station.

The first crew of the Salyut 7 – Anatoli Berezovoi and Valentin Lebedev – arrived on May 13, 1982 aboard a Soyuz spacecraft.

The Salyut 7 carried three solar panels, two in lateral and one in dorsal longitudinal positions, but they now had the ability to mount secondary panels on their sides. Internally, the Salyut 7 carried electric stoves, a refrigerator, constant hot water and redesigned seats at the command console (more like bicycle seats). Two portholes were designed to allow ultraviolet light in, to help kill infections. Further, the medical, biological and exercise sections were improved, to allow long stays in the station. The BST-1M telescope used in Salyut 6 was replaced by an X-ray detection system.

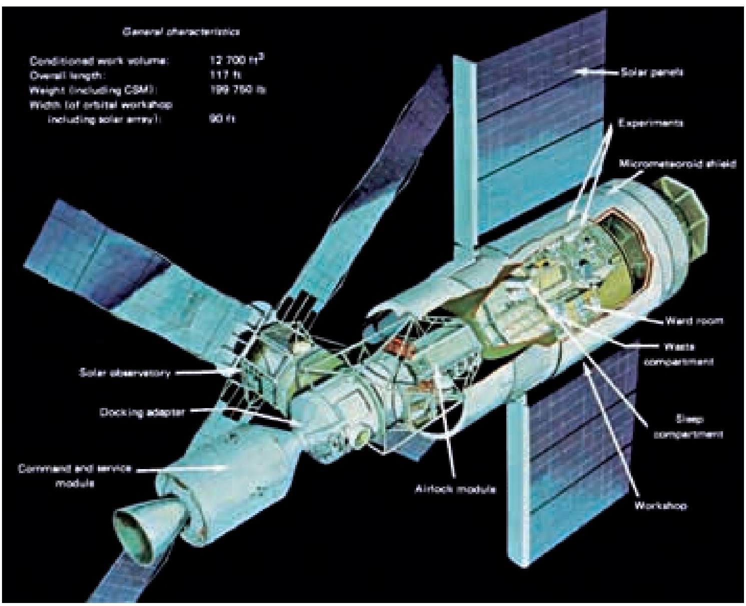
On May 6, 1986 Leonid Kizim and Vladimir Solovyov became the last cosmonauts to visit the Salyut 7space station, after which the programme was scrapped.

Skylab

While the Soviets were the first to launch the space station with the Salyut programme, reclaiming their pride in the field of space, the Americans weren't far behind. On May 14, 1973, NASA launched a Saturn V rocket carrying its first space station, Skylab. This too would be a monolithic station, constructed in its entirety on the ground before being launched into space. Crew would use the Apollo spacecraft to board it.

Designed for long duration missions, the Skylab programme objectives were twofold: (i) To prove that humans could live and work in space for extended periods, and (ii) to expand our knowledge of solar astronomy well beyond Earth-based observations. Successful in all aspects despite early mechanical difficulties, three three-man crews occupied the Skylab workshop for a total of 171 days, 13 hours. It was the site of nearly 300 scientific and technical experiments: medical experiments on humans' adaptability to zero gravity, solar observations, and detailed Earth resources experiments.

Skylab weighed about 100 tons and had a volume of 283.17 cubic metres. It was separated into two 'floors'; the upper floor contained storage lockers and a large empty space for conducting experiments, and two airlocks, one pointed



A schematic of the Skylab space station

towards the earth and the other towards the sun; the lower floor was divided into rooms including a dining room with a table, three bedrooms, a work area, a bathroom and a shower. The floors consisted of an open gridwork that fit cleats on the bottom of the astronauts' shoes.

The station was also equipped with an airlock module for the many spacewalks that were required to change film in the external cameras and make repairs to the station. The Apollo Command and Service Modules remained attached to the station's docking mechanism for the duration of the astronauts' stays aboard the station.

The largest piece of scientific equipment was the Apollo Telescope Mount (ATM), which had its own solar panels for electricity generation and was used to make apectrographic analyses of the Sun without interference from Earth's atmosphere.

One of Skylab's most important functions was to study the feasibility of long-duration space missions. As a result, the ongoing activity of astronauts just going about their daily lives in orbit was one of the greatest of all the scientific experiments aboard the station. Though they were free-falling in Earth orbit, travelling at 16,000 miles per hour, the Skylab crew members said that everyday life on the station was actually pretty normal.

Their daily science assignments would rotate every day. Each took turns on things such as solar observation, and the astronaut who was the "guinea pig" for the medical evaluations one day would be performing those same evaluations on one of his crewmates the next. The crews also had devised their own small experiments, some of which were later turned into educational videos for students worldwide.

The capability to conduct longer manned missions was conclusively demonstrated in Skylab, first by the crew returning from the 28 day mission and, more forcefully, by the good health and physical condition of the second and third Skylab crews who stayed in weightless space for 59 and 84 days respectively. Also, resupply of space vehicles was attempted for the first time in Skylab and was proven to be effective.

Extra-vehicular activities (EVAs) had been scheduled from the beginning to change out the film in the Apollo Telescope Mount. However the EVAs eventually became necessary to repair the station.

The effectiveness of Skylab crews exceeded expectations, especially in their ability to perform complex repair tasks. They demonstrated excellent mobility, both internal and external to the space station, showing man to be a positive asset in conducting research from space. By selecting and photographing targets of

opportunity on the Sun, and by evaluating weather conditions on Earth and recommending Earth Resources opportunities, crewmen were instrumental in attaining extremely high quality solar and Earth oriented data.

Upon completion of the engineering tests, Skylab was positioned into a stable attitude and systems were shut down. It was expected that Skylab would remain in orbit eight to ten years. However, in the fall of 1977, it was determined that Skylab was no longer in a stable attitude as a result of greater than predicted solar activity.

The empty Skylab spacecraft returned to Earth July 11, 1979 scattering debris over the Indian Ocean and the sparsely settled region of Western Australia.

Space Shuttle

After the Apollo-Soyuz mission, the increasing cooperation of space efforts between the two space programmes led to rapid advances in discovery. While the Skylab was retired in 1979, NASA still had access to the Salyut space stations and was working with the European Space Agency on the Soviet Space Programme's upcoming Mir space station.

One of the major technological breakthroughs came at the time of the retirement of the Skylab, when NASA perfected its space shuttle fleet of aircraft.

The space shuttle is the world's first reusable spacecraft, and the first spacecraft in history that can carry large satellites both to and from orbit. The shuttle launches like a rocket, manoeuvres in Earth orbit like a spacecraft and lands like an airplane. Each of the five space shuttle orbiters – Discovery, Atlantis Challenger, Endeavour, Columbia – were designed to fly at least 100 missions. The Enterprise was the only shuttle to be used only for tests and it never made it into space. After testing through the late 70s, the first Space Shuttle Columbia was launched in 1981. This was soon followed by Challenger (1983), Discovery (1984), Atlantis (1985), and Endeavour (1992, built after the Challenger's accident in 1986).

The space shuttle consists of three major components: the Orbiter which houses the crew; a large external fuel tank that holds fuel for the main engines; and two solid rocket boosters which provide most of the shuttle's lift during the first two minutes of flight. All of the components are reused except for the external fuel tank, which burns up in the atmosphere after each launch.

The Orbiter is both the brains and heart of the Space Transportation System (STS), the official title for the space shuttle programme. About the same size and weight as a DC-9 aircraft, the Orbiter contains the pressurized crew compartment (which can normally carry up to seven crew members), the huge cargo bay, and the three main engines mounted on its aft end.

The cockpit, living quarters and experiment operator's station are located

in the forward fuselage of the Orbiter vehicle. Payloads are carried in the mid-fuselage payload bay, and the Orbiter's main engines and maneuvering thrusters are located in the aft fuselage.

Forward Fuselage

The cockpit, living quarters and experiment operator's station are located in the forward fuselage. This area houses the pressurized crew module and provides support for the nose section, the nose gear and the nose gear wheel well and doors.

Crew Module

The 65.8-cubic-metre crew station module is a three-section pressurised working, living and stowage compartment in the forward portion of the Orbiter. It consists of the flight deck, the middeck/equipment bay and an airlock. Outside the aft bulkhead of the crew module in the payload bay, a docking module and a transfer tunnel with an adapter can be fitted to allow crew and equipment transfer for docking and extravehicular operations. The two-level crew module has a forward flight deck with the commander's seat positioned on the left and the pilot's seat on the right.

The flight deck is designed in the usual pilot/co-pilot arrangement, which permits the vehicle to be piloted from either seat and permits one-man emergency return. Each seat has manual flight controls, including rotation and translation hand controllers, rudder pedals and speed-brake controllers. The flight deck seats four. The on-orbit displays and controls are at the aft end of the flight deck/crew compartment. The displays and controls on the left are for operating the Orbiter, and those on the right are for operating and handling the payloads. More than 2,020 separate displays and controls are located on the flight deck.

Six pressure windshields, two overhead windows and two rear-viewing payload bay windows are located in the upper flight deck of the crew module, and a window is located in the crew entrance/exit hatch located in the midsection, or deck, of the crew module.

The middeck contains provisions and stowage facilities for four crew sleep stations. Stowage for the lithium hydroxide canisters and other gear, the waste management system, the personal hygiene station and the work/dining table is also provided in the middeck.

The nominal maximum crew size is seven. The middeck can be reconfigured by adding three rescue seats in place of the modular stowage and sleeping provisions. The seating capacity will then accommodate the rescue flight crew of three and a maximum rescued crew of seven.

Airlock

The airlock provides access for EVAs. It can be located in one of several places: inside the Orbiter crew module in the middeck area mounted to the aft bulkhead, outside the cabin also mounted to the bulkhead or on top of a tunnel adapter that can connect the pressurized Spacehab module with the Orbiter cabin. A docking module can also serve as an EVA airlock.

The airlock contains two spacesuits, expendables for two six-hour payload EVAs and one contingency or emergency EVA, and mobility aids such as handrails to enable the crew to perform a variety of tasks. The airlock allows two crewmen room for changing spacesuits.

Midfuselage

In addition to forming the payload bay of the Orbiter, the midfuselage supports the payload bay doors, hinges and tiedown fittings, the forward wing glove and various Orbiter system components.

Each payload bay door supports four radiator panels. When the doors are opened, the tilting radiators are unlatched and moved to the proper position. This allows heat radiation from both sides of the panels, whereas the four aft radiator panels radiate from the upper side only.

The Remote Manipulator System (RMS) is a 15.2-metre-long articulating arm remotely controlled from the flight deck of the Orbiter. The elbow and wrist movements permit payloads to be grappled for deployment out of the payload bay or retrieved and secured for return to Earth.

A television camera and lights near the outer end of the arm permit the operator to see on television monitors what his hands are doing. In addition, three floodlights are located along each side of the payload bay.

Aft Fuselage

The aft fuselage consists of the left and right orbital manoeuvring systems, Space Shuttle main engines, body flap, vertical tail and Orbiter/external tank rear attachments.

The forward bulkhead closes off the aft fuselage from the midfuselage. The upper portion of the bulkhead attaches to the vertical tail. The internal thrust structure supports the three Space Shuttle main engines, low pressure turbopumps and propellant lines.

The shuttle has the most reliable launch record of any rocket now in operation. Since 1981, it has boosted more than 1.36 million kilograms (3 million pounds) of cargo into orbit. More than than 600 crew members have flown on its mis-

sions. Although it has been in operation for more than 20 years, the shuttle has continually evolved and is significantly different today than when it first was launched. NASA has made literally thousands of major and minor modifications to the original design that have made it safer, more reliable and more capable today than ever before.

The longest the shuttle has stayed in orbit on any single mission is 17.5 days on mission STS-80 in November 1996. Normally, missions may be planned for anywhere from five to 16 days in duration. The shuttle is designed to reach orbits ranging from about 185 kilometres to 643 kilometres high.

In 2011, NASA finally retired the Space Shuttle fleet after 30 years of service as the space research organisation is focussing more on manned interplanetary missions. The final space shuttle mission, STS-135, ended on July 21, 2011 when Atlantis rolled to a stop at its home port, NASA's Kennedy Space Centre in Florida.

Spacelab

During development of the space shuttle in the 1970's, NASA recognized the need for a facility to allow scientists to conduct experiments while in orbit. Under a cooperation agreement with NASA, the European Space Agency (ESA) built a modular research laboratory that would fit inside the Shuttle's cargo bay, called the Spacelab.

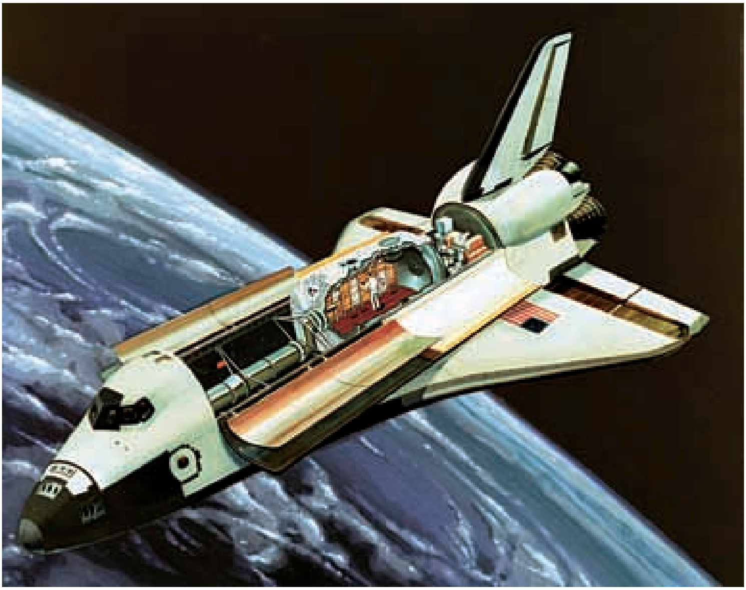
On what was only the ninth Shuttle mission, Spacelab-1 was launched on November 28, 1983. Spacelab was designed to fly in the Space Shuttle cargo bay and enabled scientists to perform a wide range of experiments in microgravity.

The Spacelab system comprised two laboratory modules in short and long versions with airlocks and optical windows, a tunnel and five separate pallets, which could be mounted separate from the Spacelab and exposed experiments to the space environment.

The habitable laboratory module is a room much like the inside of the passenger cabin of a large jet. Three mission and payload specialists can work there simultaneously, surrounded by research and control apparatus in an almost Earth-like environment. They breathe normal air, wear conventional clothes, and set the temperature and humidity to their own liking. Except for weightlessness, they can do their research almost as if they were in any modern high-technology laboratory in their campus, industrial, or government research centres on Earth.

The U-shaped pallet in the rear of the cargo bay serves as a base for research equipment needing a more open view than is feasible from the module, or requiring direct exposure to the radiations and vacuum of outer space.

A pallet weighs 1,200 kilograms, is 4 metres wide and 3 metres long, and can



Spacelab was a versatile laboratory carried in the Space Shuttle's cargo bay for special research flights. Its various elements could be combined to accommodate the many types of scientific research that could best be performed in space

support a ton of instruments for each meter of its length – about 3 tons altogether if evenly loaded. With its instruments, the pallet becomes a scientific observatory for studies in astronomy, space physics, and Earth sciences.

Some pallet-mounted instruments are self-contained and automated and require no human intervention during flight. Others need to be switched on and off, guided, or adjusted-from controls inside the core module, from the aft flight deck, or remotely from the ground by radio command.

The ESA also made a special component for pallet-only missions. The igloo canister – measuring 10 feet tall, 5 feet in diameter and weighing about 1130 kgs) was mounted beside a pallet, where it held subsystems that supplied power and other utilities to instruments and experiments on the pallet.

The Spacelab system was used on 25 Shuttle flights until 1998, when the laboratories were retired after in-orbit scientific work was transferred to the International Space Station.

Mir

In the 1980s, after the Skylab was retired and Salyut was getting ready to

be put out of service, the three major space agencies in the world – Soviet Space Programme, NASA and ESA – collectively turned their gaze to the Mir space station that the Soviets were planning.

Launched on February 26, 1986, Mir endured 15 years in orbit, three times its planned lifetime. In fact, it outlasted the Soviet Union that launched it into space! Mir translates into English as “world,” “peace,” and “village”. This would also be the first ‘modular’ space station as opposed the ‘monolithic’ approach of the Salyut and the Skylab.

Over the course of its 15 years in space, Mir hosted 125 cosmonauts and astronauts from 12 different nations. It supported 17 space expeditions, including 28 long-term crews. It raised the first crop of wheat to be grown from seed to seed in outer space.

In 2001, it was decided that Mir had reached the end of its useful life.

Russia's Mir space station is backdropped over the blue and white planet Earth in this medium range photograph recorded during the final fly-around of the members of the fleet of NASA's shuttles.

It needed to be disposed of safely and in a controlled manner. The Russian Aviation and Space Agency announced that the re-entry of the station will take place in March of that year.

A fuelled Progress vehicle was launched in January and docked onto the space station. The engines of the Progress vehicle were fired several times at regular intervals to “brake” and slow down Mir, lowering it into the Earth’s atmosphere.

Most of Mir burnt up in the atmosphere, as normally occurs with re-entering space objects that have to be disposed of. However, some pieces did impact on the ocean surface, creating an effect similar to the crash landing of one or two small aircraft.

International Space Station

With the Cold War long over and relations between the USA, European nations and Russia better than ever before, it made a lot of sense for all the parties to get together in the formation of the next space station. Each of them already had their own plans, but the combined efforts not only proved to be more economical, but also much faster.

The International Space Station is a venture of international cooperation among NASA, the Russian Federal Space Agency (RFSA), Canadian Space Agency (CSA), Japan Aerospace Exploration Agency (JAXA), and 11 members of the European Space Agency (ESA): Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom.

Now the largest spacecraft ever built, the orbital assembly of the space station began with the launch from Kazakhstan of its first bus-sized component, the Russian-built Zarya, on November 20, 1998. The launch began an international construction project of unprecedented complexity and sophistication.

A few weeks later, Space Shuttle Endeavour carried aloft the Unity connector module in December 1998. Constructed on opposite sides of Earth, Unity and Zarya met for the first time in space and were joined to begin the orbital station’s assembly. Over the years, many more modules and other parts were added, making the ISS the behemoth it is today. Some of the more important ones are:

Zarya

The first module of the entire ISS, Zarya – Russian for “sunrise” – provided orientation control, communications and electrical power attached to the passive Unity, till later advanced modules made these tasks obsolete. It is 12.6 meters (41.2 feet) long and 4.1 meters (13.5 feet wide) at its widest point. It has an operational

lifetime of at least 15 years. Its solar arrays and six nickel-cadmium batteries can provide an average of 3 kilowatts of electrical power. Its side docking ports accommodate Russian Soyuz piloted spacecraft and unpiloted Progress resupply spacecraft. The module's 16 fuel tanks combined can hold more than 6 tons of propellant. The attitude control system for the module includes 24 large steering jets and 12 small steering jets. Two large engines were available for reboosting the spacecraft and making major orbital changes.

Unity

The Unity node, the first major US-built component, made the station truly 'international' in December 1988. It is a connecting passageway to living and work areas of the International Space Station, including the US Laboratory Module and an airlock. It has six hatches that serve as docking ports for the other modules. Fabricated out of aluminium, it is 5.5 metres long, 4.6 metres and contains more than 50,000 mechanical items, 216 lines to carry fluids and gases, and 121 internal and external electrical cables using 9.7 kilometres of wire.

Zvezda

In July of 2000, Russia launched its second module which would be the first habitable headquarters of the ISS. Meaning "star" in Russian, Zvezda provided the early station living quarters (as well as the functional centre of the current Russian portion of the ISS), life support system, electrical power distribution, data processing system, flight control system and propulsion system. It also provided a communications system that includes remote command capabilities from ground flight controllers, although many of these systems are supplemented or replaced by other components now.

Zvezda made it possible for cosmonauts and astronauts to live aboard the space station and in October 2000, Bill Shepherd, Yuri Gidzenko and Sergei Krikalev launched into history as the first crew to live on the ISS. From the moment the hatch of their Soyuz spacecraft opened and they entered the fledgling space station, there have been people living and working in orbit, 24 hours a day, seven days a week, 365 days a year.

Integrated Truss Structure

Colloquially called the "backbone" of the ISS, the Integrated Truss Structure is a complex alignment of various parts that allow for mounting of solar arrays, carriers, etc. Considering that everything on the ISS runs on electricity, generating power became the most important part of the early stages of the programme.

The P6 (Port 6) Truss, launched in November 2000, brought the first huge solar arrays to the ISS. Over the next decade, more trusses would be added that increased functionality of the ISS. The S0 (Starboard 0) Truss acts as the junction from which external utilities – such as power, data, video and ammonia for the Active Thermal Control System – are routed to the pressurized modules. The S1 Truss and the P1 Truss provide structural support for the Active Thermal Control System, Mobile Transporter and one Crew and Equipment Translation Aid cart. The other trusses are used to attach equipment as well as additional solar arrays for enhanced electricity generation, storage and transfer.

Destiny

In February 2001, the US-made Destiny module was attached to the ISS, making it the primary research laboratory for US payloads, supporting a wide range of experiments and studies contributing to health, safety and quality of life for people all over the world. Destiny also featured a large window –an optical gem that makes it possible to shoot very high quality photos and video. Station crewmembers use video and still cameras at the window to record Earth's ever-changing landscapes below. In addition to its role as a science facility, Destiny also contains the control centre for the Station's robotic arm operations.

Canadarm 2 –

Canada's most major contribution to the ISS is a modified version of the robotic arm used on the space shuttles, launched in April 2001. Canadarm 2 is a robotic system that plays a key role in space station assembly and maintenance: moving equipment and supplies around the station, supporting astronauts working in space, and servicing instruments and other payloads attached to the space station. Astronauts receive robotics training to enable them to perform these functions with the arm. It is 17.6 metres long when fully extended and has seven motorised joints. This arm is capable of handling large payloads and assisting with docking the space shuttle.

Quest

The Quest Joint Airlock is a pressurised flight element consisting of two cylindrical chambers attached end-to-end by a connecting bulkhead and hatch. The airlock is the primary path for ISS spacewalk entry and departure. The addition of the airlock permits Space Station-based spacewalks to be performed without major loss of environmental consumables such as air. Quest was attached to the ISS on

July 15, 2001. Five days later, astronauts Carl Walz and Daniel Bursch were the first to perform a spacewalk through the new airlock.

Pirs
The 16-foot-long, 3,500-kg Pirs Docking Compartment was attached to the bottom, Earth-facing port of the Zvezda on September 16, 2001. Pirs has two primary functions: it serves as a docking port for the docking of transport and cargo vehicles to the ISS and as an airlock for the performance of spacewalks by two crewmembers using Russian Orlan spacesuits. In addition, it can transport fuel to and from the fuel tanks of a docked Progress or Soyuz spacecraft to Zvezda or Zarya.

Harmony
For the next six years, the ISS didn't see any modular enhancements. Several trusses were added in this period to improve functions, but the next major addition would happen only in October 2007, when the US-made Harmony module was brought on board. The installation of NASA's Harmony increased the living and working space inside the station to approximately 500 cubic metres. It also allowed the addition of international laboratories from Europe and Japan to the station, providing a passageway between three station science experiment facilities: the US Destiny Laboratory, the upcoming Kibo Japanese Experiment Module, and the soon-to-be-launched European Columbus Laboratory. The aluminium node is 7.2 metres long and 4.4 metres in diameter, weighing approximately 14,288 kilograms.

Columbus
The ESA's largest single contribution to the space station, the research laboratory module Columbus, was attached in February 2008. Columbus is about 23 feet long and 15 feet wide, allowing it to hold 10 "racks" of experiments, each approximately the size of a phone booth. Each rack provides independent controls for power and cooling, as well as communication links to earthbound controllers and researchers. These links allow scientists all over Europe to participate in their own experiments in space from several user centres and, in some cases, even from their own work locations. The Columbus laboratory's flexibility provides room for the researchers on the ground, aided by the station's crew, to conduct thousands of experiments in life sciences, materials sciences, fluid physics and other research in a weightless environment not possible on Earth. In addition, the station crew can conduct experiments outside the module within the vacuum

of space, thanks to four exterior mounting platforms that can accommodate external payloads. With a clear view of Earth and the vastness of space, external experiments can run the gamut from the microscopic world of bacteria to the limitlessness of space.

Dextre

Along with the Canadarm2, the country has also contributed what is popularly known as the 'Canada Hand'. Dextre – installed in March 2008 – is a two-armed robotic device used for servicing around the space station. The Special Purpose Dexterous Manipulator, or Dextre, is capable of handling the delicate assembly tasks usually handled by astronauts during space walks. It has built-in grasping jaws, a retractable socket drive, a monochrome TV camera, lights, and an umbilical connector that can provide power, data, and video to/from a payload.

Kibo

The same Space Shuttle Endeavour that carried Dextre also had Japan's first major contribution to the ISS. JAXA's Experiment Module called Kibo (Japanese for "hope") is Japan's first human space facility and enhances the unique research capabilities of the ISS. Experiments focus on space medicine, biology, Earth observations, material production, biotechnology and communications research. The Pressurised Module research facility – about the size of a tour-bus – is a shirt-sleeve environment in which astronauts conduct microgravity experiments. The Exposed Facility is a unique platform on the ISS that is located outside of the Pressurized Module and is continuously exposed to the space environment. The platform can hold up to 10 experiment payloads at a time and measures 5.6 metres wide, 5 meters high and 4 metres long. Items positioned on the exterior platform focus on Earth observation as well as communication, scientific, engineering and materials science experiments. Astronauts exchange experiment payloads or hardware from the Pressurized Module through the scientific airlock using the Kibo Remote Manipulator System (RMS). The RMS consists of two robotic arms – Main Arm and the Small Fine Arm for delicate operations – that support operations on the outside.

Poisk

The Russian Mini-Research Module 2, Poisk (Russian for "search", "seek" or "explore") docked to the space-facing port of the Zvezda service module on November 12, 2009. It provides an additional docking port for visiting

Russian spacecraft and will serve as an extra airlock for spacewalkers wearing Russian Orlan spacesuits.

Tranquility

The Tranquility node was connected to the Earth-facing side of the Unity node in February 2010. The pressurized section provides additional room for crew members and many of the space station's life support and environmental control systems already on board. These systems include air revitalisation, oxygen generation and water recycling. A waste and hygiene compartment and a treadmill also will be relocated from other areas of the station. It also provides an additional docking point for space shuttles and other crew vehicles visiting the station. Attached to the node will be Cupola, a unique work module with six windows on the sides and one on top.

Rassvet

The Russian module Rassvet – which translates as "dawn" – was attached to the ISS in May 2010, where it provides an additional docking port for Russian Soyuz and Progress vehicles. Weighing more than 5000 kilograms and measuring 6 metres in length and 2.3 metres in diameter, Rassvet will host a wide variety of biotechnology and biological science experiments and fluid physics and educational research. The module contains a pressurised compartment with eight workstations equipped with facilities such as a glovebox to keep experiments separated from the in-cabin environment; two incubators to accommodate high- and low-temperature experiments; and a custom platform that protects payloads and experiments from onboard vibrations. The module contains four other workstations, complete with mechanical adapters, to install payloads into roll-out racks and shelves.

Leonardo

When the ISS was first conceived, the Italian Space Agency was assigned the task of building Multi-Purpose Logistics Modules – pressurised modules that would be used to ferry cargo to and from the ISS aboard shuttle flights. In early 2011, the one of the three MPLMs, Leonardo, was refitted, redesigned and permanently attached to the ISS. The cylindrical module is approximately 6.5 metres long and 4.5 metres in diameter. It can carry up to 10 tons of cargo packed into 16 standard Space Station equipment racks. Of the 16 racks the module can carry, five can be furnished with power, data and fluid to support a refrigerator freezer. The extra space it provides will give the station's resident crew what amounts to a giant

new float-in closet to help store supplies, equipment and potentially experiments aboard the orbiting laboratory, helping the station continue its mission.

And of course, this is still a work in progress. NASA has retired of its space shuttle fleet so its involvement in the ISS is expected to be lesser over the coming years, but the other agencies are expected to continue working on it for some time.

Including the huge solar arrays, the International Space Station is a little smaller than a cricket stadium. Inside its pressurized modules, where residents live, work and sometimes play, it is as large as a five-bedroom home, with two bathrooms, a personal gymnasium and the ultimate 360-degree bay window on the world. Its total habitable volume is more than 12,000 cubic feet, and will only expand when Russia launches its next module – Nauka – in 2012.

Over 200 individuals representing 16 countries have visited the complex. Around 20,000 meals have been eaten aboard the station since the first crew took up residence in 2000. Through the course of its lifetime, astronauts have conducted over 150 spacewalks in support of space station assembly, totalling more than 1,015 hours.

With more than 600 experiments under its belt, the orbiting laboratory has provided continuous access that allows researchers and engineers the opportunity to constantly fine-tune their investigations in the unique, nearly zero-gravity environment. As a research outpost, the station is a test bed for future technologies and a research facility for new, advanced industrial materials, communications technology, medical research and more.

The International Space Station is an example of cooperation by humans and robots that is expected to become a mainstay of space exploration throughout our solar system.

But of course, it isn't going to be the only space station in the future either. China has already launched its own and other countries with space programmes, such as India, are expressing a keen interest on doing the same.

OTHER COUNTRIES & PRIVATE PROGRAMMES

China and India jumpstart their space programmes and kick off the new Space Race, while private firms also get in on the act

The US, Russia and...

The United States and Russia are undoubtedly at the forefront of space research in the world. Russia has managed to be the first to almost every major milestone in the area, and the US, of course, has been the only country to put a man on the moon. But of course, they aren't the only countries to have a capable space programme. China and India are the two new global powers in space research.

China

It would come as no surprise that China has been looking into space research from around the same time as USA and Russia. Chairman Mao was the first to recognise the military potential and China had successfully built and tested its first InterContinental Ballistic Missile (ICBM) as early as 1966. Following this, there were a couple of attempts at catching up with the two Cold War nations in the 70s and 80s, but the early spacecraft that China designed never quite worked out.

Bolstered by the strong economy in the 1990s, there was a renewed focus on the space programme. China, in effect, has two major space agencies: the PLA (People's Liberation Army) for crewed and military programs, and the CNSA (China National Space Administration) for civil/scientific

A model of the Shenzhou spacecraft

projects. With the advances already made by the US and Russia, along with China's indigenous Long March rocket that was capable of going into space, it became a little easier to develop the technology needed to send a manned mission into orbit.

The Shenzhou programme was launched with this specific purpose of carrying a 'taikonaut' – a variant of the official 'taikongaut'. Tai Kon, in Chinese, means cosmos. In 1999, an unmanned Shenzhou spacecraft was launched successfully.

The Shenzhou (Chinese for 'divine ship') spacecraft is based on the three-seat Russian Soyuz capsule, although extensive modifications have been made. It consists of three modules: a propulsion section, a conical re-entry

capsule, and an orbiter. The capsule was equipped with all that would be needed for a manned flight.

Although modelled after the Soyuz, it is considered much safer due to a number of technological advances to the launch vehicle and the launch escape system, deemed critical following the Columbia disaster.

The improved launch escape system allows the crew to escape the pod before liftoff via cables, high-speed elevator, or ejection seats. The escape tower can fire to pull the capsule and orbital module away from the booster in the event of a major booster malfunction from 15 minutes before launch to the point of escape tower jettison at approximately T+120 seconds. The escape tower can be activated automatically by the fault monitoring system or by ground control or manually by the astronauts. Additionally, the escape pod is equipped with improved life-support systems for the crew.

The chosen booster rocket was the Long March-2F, which consists of two core stages, a payload fairing, an escape tower, and four liquid-fuel, strap-on boosters. The rocket has improved guidance and control equipment, upgraded engines, a fault monitoring management system, and its craft shell has been reinforced to withstand greater extremes of heat and vibration.

After three more successful tests, it was deemed safe to send a taikonaut on board. Shenzhou 5 was the fifth spacecraft in the series and the first to contain a human presence. The spacecraft, manned by Lt. Col. Yang Liwei, was launched on October 15, 2003. Liwei orbited the Earth for nearly 21.5 hours before landing in the grasslands of Inner Mongolia. While in orbit, the taikonaut dined on specially prepared versions of Chinese food, talked with his wife and son, and took a three hour nap in addition to performing various planned activities. A total of 14 orbits were made.

Yang Liwei, the first Chinese 'taikonaut' to fly into space on an indigenously made spacecraft

The Long March-2F consists of two core stages, a payload fairing, an escape tower, and four, liquid-fuel, strap-on boosters. The rocket has improved guidance and control equipment, upgraded engines, a fault monitoring management system, and its craft shell has been reinforced to withstand greater extremes of heat and vibration.

With the Shenzhou 5, China became only the third nation in history

to send a man into space with their own space programme. Shenzhou 6 was subsequently launched on October 12, 2005. It carried two Chinese astronauts in the re-entry capsule to orbit around for about five days. The re-entry capsule separated from the orbiter module and parachuted down on Inner Mongolia. The orbiter module continued to do scientific research.

Shenzhou 7 is a Chinese manned satellite that was launched on September 25, 2008. Measuring 2.8 metres in diameter and 9.5 metres high, the craft carried three astronauts for a three day mission in a return capsule. One of the astronauts made a brief spacewalk, mainly to test the new spacesuit called Feitian (named after the goddess who could fly). The successful mission and the spacewalk were reported as an imminent precursor to building a space station, Tiangong, in 2010.

Tiangong 1, which means heavenly palace in English, was launched from Jiuquan on September 29, 2011 by a Long March 2F rocket. It weighed approximately 8506 kg and measured 12 metres long with a diameter of 3.3 metres.

Tiangong 1 is the first Chinese space laboratory module launched on a critical test flight to demonstrate the vital docking technology required for a future space station. The new module will be mainly used to carry out the rendezvous and docking test, as well as the mastering of the technologies related to rendezvous and docking and accumulate the experience for the construction, management and operation of a space station. It will be positioned several hundred miles above Earth and is composed of two cylindrical sections with a docking port on its front-end. The two modules are known as the experimental module and the resource module.

The spacecraft is expected to stay in orbit for two years and rendezvous and dock with three different spaceships. At least one of the future launches is to be manned and the taikonaut of that launch will stay on-board for a maximum of two weeks. China's goal is to build a space station by 2020, when the International Space Station is scheduled to retire.

Shenzhou 8 became the next unmanned Chinese spacecraft when it was launched on October 31, 2011. It had a three-week mission, during which time it docked twice with the unmanned space module TianGong 1. This served as a technology test for future space station docking and science experiments, as well as subsequent manned Shenzhou visits to Tiangong 1.

China is rapidly ramping up its space programme and has already successfully sent a lunar probe. It has announced its plans to send a man to the moon by 2025, along with setting up an observatory on the Earth's natural

satellite. It has also announced plans of further deep space exploration using this lunar observatory as the base.

India

One of the main reasons that China has accelerated its space programme is because of the emergence of India as a viable competitor in the space field. Indeed, some experts are calling the competition between these two emerging economies the New Space Race.

India's indigenous efforts towards a space programme have been fairly recent. Of course, it won't be the first Indian to go into space, which is an honour held by Wing Commander Rakesh Sharma of the Indian Air Force, who went aboard a Soyuz spacecraft to the Salyut 7 satellite in 1984.

The country's main space agency, the Indian Space Research Organisation (ISRO), has announced that it plans to send a man into lower-orbit by 2016, putting it a fair distance behind the Chinese programme. However, it also plans on sending a man onto moon by 2020 – an ambitious project, given the time period and its current state. The project did receive a boost, though, when ISRO successfully launched the Chandrayaan lunar probe.

ISRO is currently working on developing a spacecraft based partially on the Mercury spacecraft and partially on the Soyuz, which will carry a two-member crew into orbit. Since the space agency hasn't released any official specifications about the device, information is available only through different news reports and hence is a bit sketchy. Expected to weigh about 4 ton kilograms, it will be launched by the GSLV-MK-III rocket launcher.

The space capsule will have life control and environment control systems, along with emergency escape systems more advanced than the Soyuz spacecraft. An illustration of the spacecraft that ISRO chairman G. Madhavan Nair showed in a presentation was interpreted by space site Astronautix as depicting a main engine and smaller orientation engines arranged in a light package around the base of the capsule, indicating an earth-orbit manoeuvring capability was to be included. The nose of the original version of the OV was free for a docking mechanism, but primary entry was evidently through a side hatch secured by explosive bolts.

ISRO is currently working to set up an institute to train astronauts in Bangalore.

Private programmes

Apart from China and India, other countries like Iran, Malaysia and Ecuador

are also looking at launching manned missions into space eventually. But the closest to completion is not any nation – it comes from several privately owned companies.

SpaceShipOne

The Ansari X Prize was a competition organised by the X Prize Foundation and funded by Iranian entrepreneurs Amir Ansari and Anousheh Ansari – who was, incidentally, the world's first self-funded space tourist. The competition was a challenge to a private organisation to come up with a viable reusable manned spacecraft that could be flown on two missions within a span of 14 days.

Burt Rutan, an American aerospace engineer who gained fame for the Voyager (the first aircraft to circumnavigate the globe without having to stop for fuel) took up the challenge with his firm Scaled Composites and won it with the SpaceShipOne in October 2004 when it crossed the 100-kilometre Karman line.

Unlike usual space launches, the SpaceShipOne wasn't boosted into the air by a rocket. Instead, it was attached to a larger aircraft called the WhiteKnightOne, which took it into the skies and let it loose, whereupon it gathered wind and soared upwards.

SpaceShipOne is a three-place, high-altitude research rocket, designed for sub-orbital flights to 100 km altitude. The unique configuration allows aircraft-like qualities for boost, glide, and landing. The ship converts (via pneumatic-actuated feather) to a stable, high-drag shape for atmospheric entry. This "care-free" configuration allows a "hands-off" re-entry and greatly reduces aero/thermal loads.

The WhiteKnight aircraft carrying the SpaceShipOne before its further ascent into space

Designed for a shirt-sleeve environment, the 60- diameter cabin has a space-qualified Environmental Control System, as well as dual-pane windows. The ship uses three flight control systems – manual-subsonic, electric-supersonic and cold-gas RCS.

SpaceShipOne's hybrid rocket motor is a non-toxic, liquid nitrous-oxide/rubber-fuel hybrid propulsion system. The avionics onboard provide the pilot with the precise guidance information needed to manually fly for boost and re-entry. It also provides guidance for approach and landing and vehicle health monitoring. The unit stores and telemeters flight test data to Mission Control.

The WhiteKnightOne is a manned, twin-turbojet research aircraft intended to provide a high-altitude airborne launch of SpaceShipOne. It is equipped with everything a spacecraft usually is, except rocket propulsion. The WhiteKnightOne's cockpit, avionics, ECS, pneumatics, trim servos, data system, and electrical system components are identical to those installed on SpaceShipOne.

There is an added benefit of the WhiteKnightOne in its ability to serve as a training vehicle. Its high thrust-to-weight ratio and enormous speed brakes allow the astronauts in training to practice space flight manoeuvres such as boost, approach, and landing with a very realistic environment. Thus, the aircraft serves as a high-fidelity moving-base simulator for SpaceShipOne pilot training.

Other White Knight mission capabilities include: reconnaissance, surveillance, atmospheric research, data relay, telecommunications, imaging & booster launch for micro-satellites.

SpaceShipTwo

The success of the SpaceShipOne led to several experts calling it the advent of private space flights. And sure enough, Scaled Composites found enough people knocking on their doors. Rutan eventually chose a partner in Sir Richard Branson and they together formed an alliance called The Spaceship Company for research purposes, while Branson would go on to form Virgin Galactic for commercial spaceflights in the future.

Together, they designed and built the SpaceShipTwo, a follow-up to the SpaceShipOne, which has not yet officially said when it will begin commercial spaceflights. Yet, over 400 tickets have already been booked at over $200,000 per ticket.

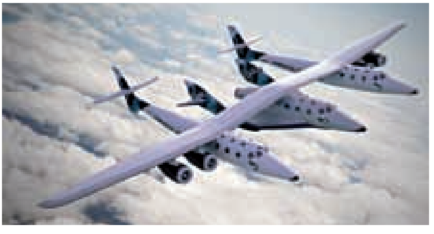
SpaceShipTwo will be powered by a unique hybrid rocket motor, which is currently under development. The twin fuselage and central payload area

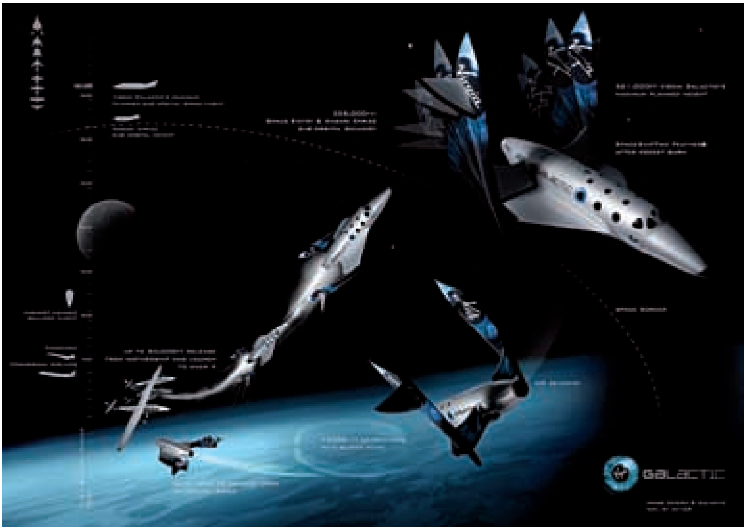
An artist's representation of the SpaceShipTwo in space

configuration allow for easy access to WhiteKnightTwo and the spaceship for passengers and crew; the design also aids operational efficiencies and turnaround times.

Perhaps the most innovative safety feature employed by SpaceshipOne and now SpaceShipTwo is the unique way it returns into the dense atmosphere from the vacuum of space. This part of space flight has always been considered as one of the most technically challenging and dangerous and Burt Rutan was determined to find a failsafe solution which remained true to Scaled Composite's philosophy of safety through simplicity. His inspiration for what is known as the feathered re-entry was the humble shuttlecock, which relies on aerodynamic design and laws of physics to control speed and attitude.

Once out of the atmosphere the entire tail structure of the spaceship can be rotated upwards to about 65 degrees. The feathered configuration allows an automatic control of attitude with the fuselage parallel to the horizon. This creates


The WhiteKnightTwo aircraft carrying the SpaceShipTwo before its further ascent into space



The detailed flight of the SpaceShipTwo

very high drag as the spacecraft descends through the upper regions of the atmosphere. The feather configuration is also highly stable, effectively giving the pilot a hands-free re-entry capability, something that has not been possible on spacecraft before, without resorting to computer controlled fly-by-wire systems. The combination of high drag and low weight (due to the very light materials used to construct the vehicle) mean that the skin temperature during re-entry stays very low compared to previous manned spacecraft and thermal protection systems such as heat shields or tiles are not needed. During a full sub-orbital spaceflight, at around 70,000 feet following re-entry, the feather lowers to its original configuration and the spaceship becomes a glider for the flight back to the spaceport runway.

WhiteKnightTwo, or Eve, is the mothership and launch platform for SpaceShipTwo. Due to the demanding design requirements of this vehicle, WhiteKnightTwo has become the world's largest all carbon composite aircraft with an amazing 140 foot wing span. Powered by four Pratt and Whitney PW308A engines, it has a unique heavy lift, high-altitude capability and an open architecture design which provides for maximum versatility in the weight, mass, and volume of its payload. It has the power, strength and manoeuvrability to provide for pre space-flight, positive G force and zero G astronaut training as well as a lift capability which is over 30 per cent greater than that represented by a fully-crewed SpaceShipTwo.

On an average SpaceShipTwo flight, the total time spent in sub-orbital space would be just a few minutes. And yes, inhabitants would experience zero-gravity in this! However, the total flight time from take-off to landing is expected to be around two and a half hours. Virgin Galactic has said it plans to start commercial spaceflights by 2013, although it hasn't confirmed that.

SpaceX

Scaled Composites and Virgin Galactic are focussed more on a 'luxury' space-flight. But the company that's at the forefront of emulating what national space agencies have managed is SpaceX, which has already successfully launched rockets (called the Falcon series) and even developed a spacecraft (called the Dragon) for manned missions which NASA itself has approved of.

In June 2010, the company successfully launched the Falcon 9 rocket, achieving Earth orbit. The launch vehicle is powered by a cluster of nine SpaceX-designed and developed Merlin engines. Using ultra pure jet fuel and liquid oxygen, the engines generated nearly a million pounds of thrust for the vehicle upon liftoff.

The Merlin engine is an orbit-class rocket engine and is the highest efficiency American hydrocarbon engine ever built. The Falcon 9 first stage, with a fully fuelled to dry weight ratio of over 20, has the world's best structural efficiency, despite being designed to higher human rated factors of safety.

The Dragon is a free-flying, reusable spacecraft made up of a pressurised capsule and unpressurised trunk used for Earth to LEO transport of pressurized cargo, unpressurized cargo, and/or crew members.

It weighs about 6000 kilograms with the payload, with a volume of 10 cubic metres in the pressurised area and 14 cubic metres in the unpressurised area. Dragon can support up to seven passengers and is designed for a water landing, much like the Soyuz spacecraft.

The Dragon spacecraft in orbit

It is comprised of 3 main elements: the Nosecone, which protects the vessel and the docking adaptor during ascent; the Spacecraft, which houses the crew and/or pressurized cargo as well as the service section containing avionics, the RCS system, parachutes, and other support infrastructure; and the Trunk, which provides for the stowage of unpressurized cargo and will support Dragon's solar arrays and thermal radiators.

To ensure a rapid transition from cargo to crew capability, the cargo and crew configurations of Dragon are almost identical, with the exception of the crew escape system, the life support system and onboard controls that allow the crew to take over control from the flight computer when needed. This focus on commonality minimizes the design effort and simplifies the human rating process, allowing systems critical to Dragon crew safety and ISS safety to be fully tested on unmanned demonstration flights.

For cargo launches the inside of the spacecraft is outfitted with a modular cargo rack system designed to accommodate pressurized cargo in standard sizes and form factors. For crewed launches, the interior is outfitted with crew couches, controls with manual override capability and upgraded life-support.

With the Space Shuttle retired, NASA has announced the selection of SpaceX's Falcon 9 launch vehicle and Dragon spacecraft to resupply the International Space Station. The first mission is scheduled for February 2012. Though designed to address cargo and crew requirements for the ISS, the free-flying spacecraft Dragon also provides an excellent platform for in-space technology demonstrations and scientific instrument testing. SpaceX is also currently manifesting fully commercial, non-ISS Dragon flights under the name "DragonLab". DragonLab represents an emergent capability for in-space experimentation.

Commercial Space Station

While Virgin Galactic and SpaceX are the two firms fighting to be the first to commercial spaceflight, there are two major contenders in the fight to launch the world's first commercial space station. But in the case of both Bigelow Aerospace and Orbital Technologies, it's still a dream quite far away with the technology going unproven so far, apart from a couple of satellites launched by Bigelow.

- **Orbital Technologies' Commercial Space Station –** The Commercial Space Station (CSS) will be man-tended, with a crew capability of up to seven people. Space-certified elements, modules and technologies of the highest quality and reliability will be used in the construction of the station. The CSS will be serviced by the Russian Soyuz and Progress spacecraft, as well other transportation systems available in the global

marketplace. Such arrangements are enabled through the station's unified docking system that will allow any commercial crew and cargo capability developed in the US, Europe and China.


A rendering of the commercial space station by Orbital Technologies

It will be a hub for commercial activity, scientific research and development in low Earth orbit. Orbital Technologies has several customers already under contract from different segments of industry and the scientific community, representing such areas as medical research and protein crystallization, materials processing, and the geographic imaging and remote sensing industry.

Because of its design and its orbital inclination, the CSS will serve as an emergency refuge for the ISS crew, should it become necessary.

Finally, the CSS will be a true gateway to the rest of the solar system. A short stop-over at the station will be the perfect beginning of a manned circumlunar flight, says Orbital Technologies, adding that the deep space manned exploration missions planned in the next decade would be welcome to use the CSS as a waypoint and a supply station.

- **Bigelow Commercial Space Station –** While Orbital Technologies doesn't have any actually technology to show for their efforts, Bigelow Aerospace has actually achieved quite a bit, including launching a couple of satellites using their patented inflatable module.

Inflatable systems offer the potential for a greater amount of on-orbit volume while, relative to a traditional metallic structure, taking up a small amount of rocket fairing space. Additionally, and perhaps most relevant to long-term orbital use, is the enhanced protection from radiation offered by inflatable habitats. Specifically, when exposed to cosmic rays or solar flares, traditional metallic habitats


An illustration of what hte Bigelow Commercial Space Station will look like in its final avatarstation by Orbital Technologies

can suffer from damaging secondary radiation wherein the metal that comprises the habitat's structure creates a scattering effect and/or becomes excited. In contrast, due to their use of non-metallic softgoods as their primary envelope material, inflatables can significantly reduce this dangerous phenomena.

NASA developed the expandable modules being used by Bigelow under its cancelled Transhab program. After elimination of the program, Bigelow Aerospace was granted the sole rights to the expandable module technology.

In June 2007, Bigelow Aerospace successfully launched its Genesis 2 prototype space station from a Russian Dnepr rocket. The Genesis spacecraft is an inflatable module that carries 22 cameras, sensors, and avionics to monitor and control the spacecraft. It is 4.4 metres in length and 1.6 metres in diameter but expands to about twice that diameter once in orbit about the Earth. It has an internal volume of 11.5 cubic metres. Its eight solar arrays extend out to 2.5 meters.

The Genesis series of space stations are expandable modules that will be sent into Earth orbit with the intent to provide commercial space habitats for private companies and national space agencies.

The inflatable modules are expected to be more durable and safer than rigid modules because the 1-foot outer skin is made of several layers of a material that is twice as strong as Kevlar. Inner layers are made of other protective materials that add to the safety of the walls. The inflatable walls of the Bigelow space station is expected to be able to withstand micrometeorite and space debris impacts better than rigid walls, say of the International Space Station.

The Genesis proved the concept for Bigelow's planned commercial space station, currently called the Space Complex Alpha. It will be made up of the BA 330 module, which can function as an independent space station, or several BA 330 habitats can be connected together in a modular fashion to create an even larger and more capable orbital space complex. Each module – about 330 cubic metres in volume – will contain an independent avionics system to support navigation, re-boost, docking, and other manoeuvring activities. It will also boast of four large windows coated with a film for UV protection, providing an unparalleled opportunity for both celestial and terrestrial viewing. The BA 330 can house up to six persons at a time, and utilizes two propulsion systems on the fore and aft of the spacecraft. The aft propulsion system can be refuelled and reused.

Bigelow Aerospace has currently scheduled the in-orbit assembly of the Space Complex Alpha for 2014.

LIVING IN SPACE

What's life like for an astronaut living in space? What does he eat? How does he sleep in zero-gravity? And what about when nature calls?

While we now know the various different spacecrafts and environments that are considered habitable for humans, one big question still remains: what is life like in space? How do astronauts go about conventional activities on the International Space Station – the one place in space where they live for weeks or months?.

Oxygen and water

Of course, life in space would be impossible without the two most important factors for humans to stay alive – oxygen and water.

Life support systems on the ISS must not only supply oxygen and remove carbon dioxide from the cabin's atmosphere, but also prevent gases like ammonia and acetone, which people emit in small quantities, from accumulating. Vaporous chemicals from science experiments are a potential hazard, too, if they combine in unforeseen ways with other elements in the air supply.

Most of the station's oxygen comes from a process called electrolysis, which uses electricity from the ISS solar panels to split water into hydrogen gas and oxygen gas. Each molecule of water contains two hydrogen atoms and one oxygen atom. Running a current through water causes these atoms to separate and recombine as gaseous hydrogen (H2) and oxygen (O2).

Carbon dioxide is removed from the air by a machine based on a material called zeolite, which acts as a molecular sieve, according to Jim Knox, a carbon dioxide control specialist at MSFC. The removed CO2 is vented to space. Engineers are also thinking of ways to recycle the gas.

In addition to exhaled CO2, people also emit small amounts of other gases. Methane and carbon dioxide are produced in the intestines, and ammonia is created by the breakdown of urea in sweat. People also emit acetone, methyl alcohol and carbon monoxide – which are byproducts of metabolism – in their urine and their breath. Activated charcoal filters are the primary method for removing these chemicals from the air.

The Water Recycling System (WRS) reclaims waste waters from the fuel cells, from urine, from oral hygiene and hand washing, and by condensing humidity from the air. Without such careful recycling, over 18,000 kilograms of water from Earth would be required per year to resupply a minimum of four crewmembers for the life of the station.

It might sound disgusting, but water leaving the space station's purification machines is cleaner than what most of us drink on Earth. It goes through an aggressive treatment process, giving practically ultra-pure water in the end.

The first step is a filter that removes particles and debris. Then the water passes through the "multi-filtration beds", which contain substances that remove organic and inorganic impurities. And finally, the catalytic oxidation reactor removes volatile organic compounds and kills bacteria and viruses.

However, even with intense conservation and recycling efforts, the ISS

gradually loses water because of inefficiencies in the life support system. Lost water is replaced by carrying it over from Space Shuttles (which produces water as a byproduct of its fuel process) or from the Russian Progress rocket (outfitted with large containers of water).

Food

Some foods can be eaten in their natural forms, such as brownies and fruit. Other foods require adding water, such as macaroni and cheese or spaghetti. Of course, an oven is provided in the space station to heat foods to the proper temperature. There are no refrigerators in space, so space food must be stored and prepared properly to avoid spoilage, especially on longer missions.

The food system consists of 3 different supplies of food; Daily Menu, Safe Haven, and Extra Vehicular Activity (EVA) food.

- **Daily Menu –** Foods chosen for the daily menu were selected based on their commonality to everyday eating, the nutritional content and their applicability to use in space. The Daily Menu food supply is based on the use of frozen, refrigerated, and ambient foods. Frozen food includes most entrees, vegetable, and dessert items. Refrigerated food includes fresh and fresh-treated fruits and vegetables, extended shelf-life refrigerated foods, and dairy products. Ambient foods include thermostabilized,

Astronaut James Voss appears to be trying to decide between two colors or two species of apples as he ponders them in the Zvezda Service Module on the ISS.

aseptic-fill, shelf-stable natural form foods, and rehydratable beverages. The packaging system for the Daily Menu food is based on single service, disposable containers. Food items are packaged as individual servings to facilitate in-flight changes and substitutions to preselected menus. Single service containers also eliminate the need for a dishwasher. A modular concept that maintains a constant width dimension is utilized in the package design. This design permits common interface of food packages with restraint mechanisms (stowage compartments, oven, etc.) and other food system hardware such as the meal tray. Five package sizes were designed to accommodate common serving sizes of entrees, salads, soups, and dessert items. Several fresh fruits, bread, and condiments are provided in bulk packages.

- **Safe Haven Food –** The Safe Haven food system is provided to sustain crewmembers for 22 days under emergency operating conditions resulting from an on-board failure. A goal of the system is to utilise a minimal amount of volume and weight. The Safe Haven food system is independent of the daily menu food and will provide at least 2,000 calories daily per person. The Safe Haven food system will be stored at ambient temperatures which range from 60 to 85 degrees Fahrenheit. Therefore, the food must be shelf-stable. Thermostabilized entrees and fruits, intermediate moisture foods, and dehydrated food and beverages are used to meet the shelf-stable requirement. The shelf life of each food item is a minimum of two years.
- **EVA Food –** EVA food consisting of food and drink for 8 hours (500 calories of food and 1 litre of water) will be available for use by a crewmember during each EVA activity. EVA water and food containers is cleaned and refilled with galley subsystems.

Condiments, such as ketchup, mustard and mayonnaise, are provided. Salt and pepper are available but only in a liquid form. This is because astronauts can't sprinkle salt and pepper on their food in space. The salt and pepper would simply float away. There is a danger they could clog air vents, contaminate equipment or get stuck in an astronaut's eyes, mouth or nose.

As on Earth, space food comes in disposable packages. Astronauts must throw their packages away when they are done eating. Some packaging actually prevents food from flying away. The food packaging is designed to be flexible and easier to use, as well as to maximize space when stowing or disposing food containers.

Food evaluations are conducted approximately eight to nine months before the flight. During the food evaluation sessions, the astronaut is given

the opportunity to sample a variety of foods and beverages available for flight. A pack of information is given to each astronaut to use in planning their personal preference menus. Included in the packet is a standard menu, training menu, past flight menus the astronaut has chosen, and the baseline shuttle food and beverage list.

Astronauts select their menu approximately five months before flight. The menus are analysed for nutritional content by the nutritionists and recommendations are made to correct any nutrient deficiencies based on the Recommended Dietary Allowances.

Astronauts eat three meals a day: breakfast, lunch and dinner. Nutritionists ensure the food astronauts eat provides them with a balanced supply of vitamins and minerals. Calorie requirements differ for astronauts. For instance, a small woman would require only about 1,900 calories a day, while a large man would require about 3,200 calories. There are also many types of foods an astronaut can choose from such as fruits, nuts, peanut butter, chicken, beef, seafood, candy, brownies, etc. Drinks range from coffee, tea, orange juice, fruit punches and lemonade.

The menus are then finalized and provided to the Flight Equipment Processing Contractor (FEPC) in Houston three months before launch.

Fitness and exercise

Living in space is not the same as living on Earth. In space, astronauts' bodies change. On Earth, our lower body and legs carry our weight. This helps keep our bones and muscles strong. In space, astronauts float. They do not use their legs much. Their lower backs begin to lose strength. Their leg muscles do too. The bones begin to get weak and thin. This is very bad for astronauts' bodies. So, how do astronauts help their muscles and bones? They must exercise in space every day.

Exercise is an important part of the daily routine for astronauts aboard the station to prevent bone and muscle loss. On average, astronauts exercise two hours per day. The equipment they use is different than what we use on Earth. Lifting 100 kilograms on Earth may be a lot of work, but in space it is easy. Therefore, exercise equipment needs to be specially designed for use in space so astronauts will receive the workout needed. In space, astronauts use three pieces of exercise equipment.

- **Resistance Exercise Device:** The Resistance Exercise Device (RED) simulates weight lifting in microgravity. The system is powered by lightweight, portable SpiraFlex technology, which creates resistance by


Astronaut Sunita L. Williams, Expedition 15 flight engineer, exercises on the Cycle Ergometer

storing and delivering mechanical power.

How does it work? Special synthetic compounds called elastomers, which have the stretching properties of natural rubber, are moulded into several patented shapes. Each shape creates a different type of resistance. By varying how these parts are used – alone, linked together, or used in combination with other devices – almost any type of exercise can be achieved.

- **Treadmill with Vibration Isolation System:** When astronauts on the space station use a treadmill (made specially to work in micro-gravity), spring-loaded cords attach to both sides of the treadmill and to a harness around the runner's waist. The cords can be loaded with 66 to 100 per cent of the runner's body weight to determine the strength of the workout.
- **Cycle Ergometer:** Sometimes astronauts on the space station exercise on a cycle ergometer – sort of a glorified stationary bicycle. The astronauts use clip pedals and have the option of waist straps, back supports, and hand holds to secure themselves to the machine and then pedal away with attached weight.

Moving air is supplied to dry off the perspiration produced from exercising. Otherwise, the sweat would stick to the skin and grow thicker and thicker.

Sleeping in Space

Just like on Earth, a worker in space goes to bed at night then wakes up the next day and prepares for work all over again. There are a few differences, though.

For starts, in space, there is no up or down and there is no gravity. As a result, astronauts are weightless and can sleep in any orientation. However, they have to attach themselves to a wall, a seat or a bunk bed inside the crew cabin so they don't float around and bump into something.

Crews usually sleep in sleeping bags. On the space shuttle, astronauts can also sleep in the commander's seat, the pilot's seat or in bunk beds. There are only four bunk beds in the space shuttle. So that means on missions with five or

more astronauts, the other crewmembers have to sleep in a sleeping bag attached to their seats or to a wall.

On the space station there are two small crew cabins. Each one is just big enough for one person. Inside both crew cabins is a sleeping bag and a large window to look out in space. Currently, space station crews have three astronauts living and working in space for months at a time. Where does the third astronaut sleep? If it's okay with the commander, the astronaut can sleep anywhere in the space station as long as they attach themselves to something.

Astronaut Susan Helms slept in the huge Destiny Laboratory Module by herself while she was living aboard the International Space Station. This is on the opposite side of the station from the Service Module where her crewmates slept.


JAXA astronaut Koichi Wakata in a sleeping bag attached to the racks in the Kibo laboratory

Generally, astronauts are scheduled for eight hours of sleep at the end of each mission day. Like on Earth, though, they may wake up in the middle of their sleep period to use the toilet, or stay up late and look out the window. During their sleep period, astronauts have reported having dreams and nightmares. Some have even reported snoring in space!

The excitement of being in space and motion sickness can disrupt an astronaut's sleep pattern. Sleeping in close quarters can also be disruptive since crewmembers can easily hear each other. Sleeping in the shuttle's cockpit can also be difficult since the Sun rises every 90 minutes during a mission. The sunlight and warmth entering the cockpit window is enough to disturb a sleeper who is not wearing a sleep mask.

Hygiene

Astronauts living and working in space have the same hygiene needs as people on Earth. They wash their hair, brush their teeth, shave and go to the bathroom. However, because of the microgravity environment, astronauts take care of themselves in some different ways.

Astronauts wash their hair with a rinseless shampoo that was origi-

The toilet aboard the space station

nally developed for hospital patients who were unable to take a shower. There is no shower on the Shuttle, so astronauts must make do with sponge baths until they return home.

Many of them also have a personal hygiene kit that is attached to the wall. Personal preferences, such as the brand of toothpaste, are accommodated if possible. Dental hygiene is basically the same as on Earth, except that when astronauts brush their teeth, they can either swallow the toothpaste or spit it into a washcloth.

Because of microgravity, the space station toilet is more complex than what people use on Earth. Each Space Shuttle has a toilet that can be used by both men and women. Designed to be as much as possible like those on Earth, the units use flowing air instead of water to move waste through the system.

The astronauts have to position themselves on the toilet seat, using leg restraints and thigh-bars. The toilet – with an 8-inch opening – basically works like a vacuum cleaner with fans that suck air and waste into the commode. Each astronaut has a personal urinal funnel, which has to be attached to the hose's adapter. Fans suck air and urine through the funnel and hose into the wastewater tank.

Solid wastes are compressed and stored on-board, and then removed after landing. Waste water is vented to space, although future systems may recycle it. The air is filtered to remove odour and bacteria and then returned to the cabin. A fan system is used to force the urine to a holding tank where it is periodically ejected into space, where it vaporizes.

The toilet, which has a practically unlimited storage capacity, features a cylinder system where a plastic bag is placed in the toilet before use. The bag is then sealed and is forced to the bottom of the cylinder after each use by a plunger attached to a lever. A new bag is then placed in the toilet for the next astronaut. When the cylinder is filled, it is replaced by a new cylinder.

Clothes in the Space Station

Astronauts wear various types of clothing for all aspects of a mission to space. Whether preparing for launch, working inside the space shuttle or the space station, working outside in space, or landing back on Earth, astronauts wear the proper garments for both comfort and protection.

ISS crewmembers choose the shirts, shorts and pants they will wear in space months before they are scheduled to launch. In fact, their clothes often arrive at the space station before they do, via a Progress resupply vehicle or a space shuttle.

Space station crews can choose from either Russian or US clothing supplies. They also have the option of ordering two versions of Russian coveralls – heavy or light-duty – to work in.

Because it's expensive to take supplies into space and there's no washing machine aboard the space station – in order to save water – station crews don't change clothes as often as people do on Earth. Of course, since they don't go outside, except in a spacesuit, they don't get as dirty as people living on Earth.

On average, station crewmembers get one pair of shorts and a T-shirt for every three days of exercising. Their work shirts and pants/shorts are changed, on average, once every 10 days. Crewmembers generally get a new T-shirts to wear under their work shirts every 10 days. Underwear and socks are changed every other day, but Polartec socks – which are worn if a crewmember's feet get cold – must last a month. They also get two sweaters.

In addition, each crewmember gets a pair of running shoes to use on the station's treadmill and another pair of shoes to wear when using the station's exercise bicycle.

When a piece of clothing has been worn as many times as possible, it's placed in a bag for disposal. Very little clothing is brought back to Earth. Most of it is eventually placed in the Progress resupply vehicle before it undocks from the space station. The dirty clothing and other garbage then burns up with the Progress when it re-enters the Earth's atmosphere.

Clothes for launch and landing

During launch and entry aboard a space shuttle, crew members use the US-made orange Launch and Entry Suits (LES) or the Russian-made white Sokol suit. The two suits are similar in almost every aspect apart from the colour.

In the event of a pressure leak in the space shuttle's flight cabin, these suits would maintain a positive air pressure around the astronaut. This pro-

vides enough air pressure for the astronaut to survive the return to Earth during an emergency landing. Should an astronaut be forced to bail out over cold water, the pressurised suit would also provide thermal protection.

The suit provides an emergency oxygen system; parachute harness; parachute pack with automatic opener, pilot chute, drogue chute and main canopy; a life raft; two litres of emergency drinking water; flotation devices; and survival vest pockets containing a radio/beacon, signal mirror, shroud cutter, pen gun flare kit, sea dye marker, smoke flare and beacon. The attached parachute can be opened automatically or manually.


The Launch and Entry Suit

Space Suits

Given that the first spacewalk happened way back in 1965 and man landed on the moon in 1969, it is to be expected that the spacesuit has undergone some radical changes since then. To go through the history of each spacesuit wouldn't serve much purpose. There are three modern variants used today, the Russian Orlan space suit, the Chinese Feitian suit and the most advanced one – the American Extra-vehicular Mobility Unit (EMU).


The Extravehicular Mobility Unit spacesuit being used on a spacewalk

The EMU is like a personal mini-spacecraft. The complex garment not only protects from the extreme conditions of space, it is in itself a mobile life support system with an oxygen supply, electrical power, water-cooling equipment, ventilating fan, and an in-suit drink bag.

- **Primary Life Support Subsystem (PLSS) –** The PLSS is

worn like a backpack. It provides astronauts many of the things they need to survive on a spacewalk. Its tanks supply oxygen for the astronauts to breathe. It removes exhaled carbon dioxide. It contains a battery for electrical power.

The PLSS also holds water-cooling equipment, a fan to circulate oxygen and a two-way radio. A caution and warning system in this backpack lets spacewalkers know if something is wrong with the suit. The unit is covered with protective cloth layers.

- **Layers –** The spacesuit has 14 layers of material to protect the spacewalker. The liquid cooling and ventilation garment makes up the first three layers. On top of this garment is the bladder layer. It creates the proper pressure for the body. It also holds in the oxygen for breathing. The next layer holds the bladder layer to the correct shape around the astronaut's body and is made of the same material as camping tents. The ripstop liner is the tear-resistant layer. The next seven layers are Mylar insulation and make the suit act like a thermos. The layers keep the temperature from changing inside. They also protect the spacewalker from being harmed by small, high-speed objects flying through space. The outer layer is made of a blend of three fabrics. One fabric is waterproof. Another is the material used to make bullet-proof vests. The third fabric is fire-resistant.
- **Upper Torso –** The top of the spacesuit includes the Hard Upper Torso (HUT) and the arm assembly. The HUT covers the chest and back. It is a vest made out of fibreglass like some cars and swimming pools. The Displays and Control Module and Primary Life Support Subsystem attach to this piece. An important function of this piece is that it serves as the connection for the tubes that drain water and allow oxygen flow.
- **Displays and Control Module –** This module is the control panel for the EMU, containing switches, controls, gauges and an electronic display. The astronaut can operate the PLSS from this module.
- **Arms & Gloves –** Spacewalkers do not wear custom-made suits. Different sizes of arm assembly parts are available. Sizing rings can make the parts longer or shorter.

  Astronauts must be able to work with and pick up objects while wearing spacesuit gloves. EVA gloves are made to protect astronauts from the space environment. They are also made so spacewalkers can move their fingers as easily as possible. The fingers are the part of the body that gets coldest in space. These gloves have heaters in the fingertips. A piece

called a bearing connects the glove to the sleeve. The bearing allows the wrist to turn.

A spacewalker cannot see the front of the Displays and Control Module (DCM) while wearing the spacesuit. To see the controls, astronauts wear a wrist mirror on the sleeve. Much like the word 'ambulance' is written backwards on the top of an emergency vehicle, the settings on the DCM are also written backwards so that the wrist mirror shows them correctly. On their wrists, astronauts wear a short checklist of the tasks they will do during the spacewalk.

- **In-Suit Drink Bag –** A plastic, water-filled pouch attaches to the inside of the HUT using Velcro. A plastic tube with a valve sticks out of the bag. The tube and valve can be adjusted to be near the astronaut's mouth. Biting the valve opens the tube so the spacewalker can take a drink. Releasing the bite closes the valve again.
- **Maximum Absorption Garment –** Because spacewalks typically last more than six hours without a break, spacewalkers wear adult-sized diapers with extra absorption material under their spacesuits.
- **Liquid Cooling and Ventilation Garment –** Most long underwear keeps people warm. This underwear keeps spacewalkers cool. It is made of stretchy spandex material. Throw a complex chain of 91.5 metres of narrow tubes going through the material, water is pumped near the spacewalker's skin. The chilled water removes extra heat as it circulates around the crewmember's entire body. The vents in the garment draw sweat away from the astronaut's body. Sweat is recycled in the water-cooling system. Oxygen is pulled in at the wrists and ankles to help with circulation within the spacesuit.
- **Lower Torso –** This section is made up of spacesuit pants, boots and the lower half of the waist closure. A piece called the waist bearing helps the astronaut move and turn. A metal body-seal closure connects the lower torso to the hard upper torso.

  The lower torso has D-rings to attach tethers. Tethers are the cords that attach to the spacecraft so spacewalkers will not float away. One end of these straps is attached to the spacewalker and the other end is connected to the vehicle.

  Some suits are plain white; some have red stripes; and others have candy cane stripes. These variations help to tell one spacewalker from another.
- **Helmet –** Besides covering a spacewalker's head, the helmet has a Vent Pad. This pad directs oxygen from the PLSS and HUT to the front of the

helmet. The helmet keeps the oxygen at the right pressure around the head. The main part of the helmet is the clear plastic bubble.

The bubble is covered by the Extravehicular Visor Assembly. The visor is coated with a thin layer of gold that filters out the sun's harmful rays. The visor also protects the spacewalker from extreme temperatures and small objects that may hit the spacewalker.

A TV camera and lights can be attached to the helmet.

- **Communications Carrier Assembly (CCA) –** The CCA is sometimes called the Snoopy Cap. The astronaut wears the cap under the helmet. It has earphones and microphones. It connects to the radio on the spacesuit. Using the CCA, astronauts can talk with the rest of the crew and hear the caution and warning tones.
- **Simplified Aid for EVA Rescue (SAFER) –** SAFER is like a life jacket, worn like a backpack. If an astronaut should become untethered and float away, SAFER would help them fly back to the station. It uses small nitrogen-jet thrusters to let an astronaut move around in space using a small joystick.

FUTURE OF MANNED MISSIONS

What lies ahead in man's exploration of the vast unknown...

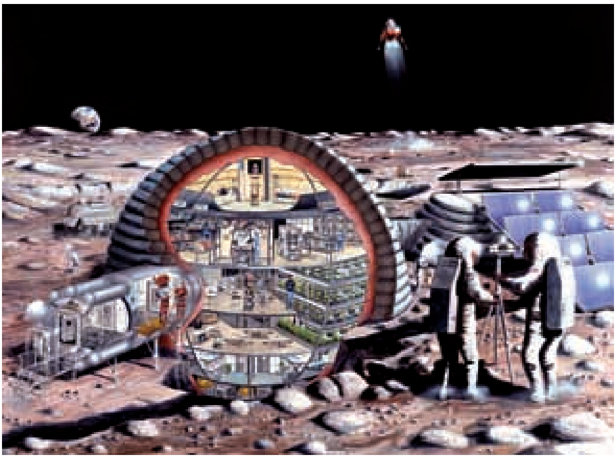
Now that man has made it a habit to go into space, what lies next in our exploration of the great beyond? It has been over 40 years since the Americans first stepped on the moon and a lot of other countries are working towards launching manned lunar missions once again.

While it isn't actually a Space Race, the two targets that everyone seems to want to achieve is the colonisation of moon and planning man's first visit another planet in the solar system – Mars.

Lunar colonies

Ever since the Apollo 11, every space agency has harboured plans of going to the moon and setting up a colony there. After the Moon Mineralogy Mapper aboard the Chandrayaan-I discovered water ice on the moon, this has gotten a bit more of a push from all parties.

Of course, no one is close to actually achieving it, even though Russia and Japan have announced plans to do so by 2025 and China has said that it plans



An artist's concept of a lunar outpost in the future

to do it by 2030. NASA was looking at lunar colonisation as part of the Constellation programme, but that was cancelled in 2010.

So far, early plans of every programme seem to be looking at inflation-deployed expandable structures as the most likely building block for a lunar base. Inflatables can be used as connectors or tunnels between crew quarters and can provide radiation shelter if covered with lunar soil/

Before the cancellation of Constellation, NASA had previously worked on a 12-foot-diameter inflatable structure made of multilayer fabric, housing technologies such as flexible structural health monitoring systems, self-healing materials and radiation protective materials. Attached to the structure is a smaller inflatable structure that serves as a demonstration airlock. Both are essentially pressurized cylinders, connected by an airtight door.

The structure looks something like an inflatable backyard bounce house for children, but it is far more sophisticated. It is insulated and heated, has power and is pressurized. On the moon, it could be used to evaluate materials, lightweight structure technologies, astronaut interfaces, dust mitigation techniques, and function with robotics and other lunar surface equipment.

Of course, this is still a pie-in-the-sky project, much like the programmes of going to Mars.

Mars500

NASA, the Russian Federal Space Agency and the China National Space Administration have all announced their intentions of going to Mars – some as early as 2030 and others as late as 2060. So far, apart from landing a few robotic probes on the Red Planet, all of the preparations are in the preliminary stage. The most ambitious and publicised part of the projects, though, is the Mars500.

The purpose of the Mars500 study is to gather data, knowledge and experience to help prepare for a real mission to Mars. Obviously there has not been effect of weightlessness, but the study also helps to determine key psychological and physiological effects of being in such an enclosed environment for such an extended period of time.

The Mars500 Crew. Standaring: (left to right) Sukhrob Kamolov, Alexandr Smoleevskiy, Diego Urbina. Sitting (left to right) Yue Wang, Alexey Sitev, Romain Charles

In order to simulate a mission to Mars, six candidates (three Russian, two European and one Chinese) have been sealed in an isolation chamber since June 2010. This group was chosen to encompass working experience in many fields, including medicine, engineering, biology and computer engineering.

Part of the chamber simulates the spacecraft that would transport them on their journey to and from Mars and another part will simulate the landing module that would transfer them to and from the Martian surface.

Following the completion of an initial 105-day isolation period in 2009, a full 520-day study was started in June 2010, which ended in November 2011.

Once sealed into the chamber, the candidates had only personal contact with each other plus voice contact with a simulated control centre and family and friends as would normally happen in a human spaceflight mission. A 20-minute


Simulated training of extra vehicular activity in the Mars500

delay was built into communications with the control centre to simulate an interplanetary mission and the crew has been given almost an identical diet to that used for the International Space Station.

As with a human spaceflight mission, the crew was free to take certain personal items, and they were supplied with books, films, personal laptops and can occupy themselves with physical exercise or their own studies.

During the isolation period, the candidates simulated all elements of the Mars mission, travelling to Mars, orbiting the planet, landing and return to Earth.

The crew was very self-reliant, organising themselves a great deal of their daily tasks. They were responsible for monitoring and maintaining the health and psychological states of themselves and each other, monitoring and controlling and maintaining systems, including life support, control resource consumption, carry out standard and non-standard cleaning and maintenance, as well as fulfilling scientific investigations.

During simulated 'Mars surface operations', the crew was divided into two groups of three people each. Once the first group 'descended' to the Martian surface, the hatch between the Martian simulation module and the rest of the facility was closed by the second group and was opened again only when the Mars surface stay simulation ended.

On November 4, 2011, Mars500's six brave volunteers stepped out of their 'spacecraft' to be welcomed by the waiting scientists – happy that the venture had worked even better than expected.

> **"If somebody had said before the flight, 'Are you going to get carried away looking at the earth from the moon?' I would have said, 'No, no way.' But yet when I first looked back at the earth, standing on the moon, I cried."**
>
> ***Alan Shepard, the American astronaut who had already become the first American in space, many years before stepping on the moon.***

The actual mission to Mars would still be a long time away, but the success of the Mars500 project has been a step in the right direction to exploring new worlds...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